DEPARTMENT OF ENERGY

Energy use and energy efficiency in UK manufacturing industry up to the year 2000

VOLUME I

Executive Summary and Main Report

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Energy Efficiency Demonstration Scheme: A Review (£8.25)
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EXECUTIVE SUMMARY

Introduction

1. This study, which has been commissioned by the Department of Energy, is a disaggregated analysis of the present pattern of energy use, and the scope for its more efficient use, in UK manufacturing industry.

2. The report of the study is in two parts:

- the sector reports, which contain detailed analyses of industrial energy use disaggregated into sectors and subsectors, are presented in Volume II;

- the main report, which is both a synthesis of the sector reports and an overview of energy efficiency in industry is presented in Volume I.

3. The sector reports analyse the large body of information contained in reports in the 'Energy Audit' and 'Industrial Energy Thrift Studies' series. Where appropriate, additional information has been sought from industry sources such as trade federation or research associations.

4. The main report discusses the general factors influencing changes in energy efficiency in manufacturing industry and describes the methodology used in the study. The findings of the sector reports are drawn together and compared with other studies. The methods used are based on a disaggregated technological approach, in which the technical and economic scope for improving energy efficiency in each major energy using process in industry is separately identified.

5. The research for this study was carried out before the Secretary of State created the Energy Efficiency Office. The study could not therefore take account of the impact on industrialists of the programmes of the Energy Efficiency Office and the energy efficiency campaign spearheaded by the Secretary of State. Research by the Energy Efficiency Office into the effectiveness of its programmes and of the campaign shows that industrialists are taking action as a result of this activity. The Office aims to produce a climate in which industrialists realise savings earlier than they might otherwise do, and indeed realise savings which might otherwise not be made at all. The success of its activities will bring forward the savings which this report shows could be in place by the year 2000.

Industrial Sectors Studied

6. Manufacturing industry has been disaggregated into seven main sectors and 44 subsectors. The main sectors are groupings of cognate subsectors. However, it is the subsectors which form the basic unit of disaggregation. As far as possible, the structure of the disaggregation follows the 1980 Standard Industrial Classification. The main sectors are as follows, with the subsectors given in brackets:

- Metals (iron and steel, aluminium, copper, lead and zinc).

- Ceramic Materials (cement, bricks, refractories, potteries, glass, miscellaneous building materials).

- Chemicals (inorganic, organic, fertilisers, polymers, dyestuffs, paints, pharmaceuticals, detergents, miscellaneous).

- Paper (paper and board making, conversion of paper and board, printing and publishing).

- Food etc. (dairy, processed foods, bakery, sugar drinks, oils and fats, miscellaneous foods, tobacco).

- Engineering (mechanical, instruments, electrical, vehicles, metal goods).

- Textiles (wool, cotton, knitted goods, textile finishing, jute and carpets, miscellaneous textiles, synthetic fibres, leather goods, footwear and clothing).

7. Energy intensive subsectors (metals, ceramic materials, bulk chemicals, paper making and textile finishing) account for 60% of the energy consumed by manufacturing industry. Their use of energy is complex, involving large amounts of process heat, often at high temperatures. On the other hand, in energy non-intensive sectors space heating tends to be the dominant use of energy.

Methodology

8. For each subsector, data on energy consumption were obtained for 1980, which is taken as the base year for the study. A technical description is given of how the energy was used in each major process or activity, and a specific energy consumption (SEC) per unit of output determined. Where possible, a physical quantity is used to measure output, e.g. tonnes of steel or cement. For some subsectors, however, the range of products is too diverse for a physical measure of output, e.g. engineering, textiles. In these cases, gross monetary output is used as a proxy for the physical output.

9. The specific energy consumption for firms or plants using best practice methods is identified. If appropriate, values of SEC representing best practice overseas are considered. However, the 'best practice' SEC is not necessarily the lowest SEC of all the plants in a subsector. Special circumstances of raw material or product type may make it unrepresentative. Care is therefore taken to ensure that the value of SEC identified as best practice is achievable by most other plants within the subsector.

10. Past trends in SEC for major energy using processes have been examined and, where the available data permitted, analysed to identify the technical changes responsible for improvements in energy efficiency. In some cases, such as the introduction of continuous casting in the iron and steel industry, or drier processing techniques in cement making, the process of technical change is incomplete in 1980 and will undoubtedly make a further contribution to the reduction in energy efficiency in the future.

11 The scope for introducing new technologies to improve energy efficiency is also examined. Some of the new technologies are already technically

proven, and may even be in commercial use overseas. Others require further research and development before they will become commercially viable.

12. The approach followed in this study does not permit the construction of a full set of energy demand projections. In practice SECs, which are the main output of the study, are not independent of either the level of production or the level of energy prices. In the study it was not possible to analyse the effects of alternative fuel price paths on energy efficiency and nor were investment appraisals carried out to check the cost-effectiveness of individual energy efficiency measures or their likely take up. The SECs shown were prepared in the context of particular assumptions about future output levels and illustrative energy demands and energy savings can be obtained by multiplying the SECs by these same output assumptions. This has been done for two sample scenarios, the output assumptions being derived from the middle upper (YU, BU) and middle lower (YL, BL) scenarios of the Department of Energy's 1982 Energy Projections. The high and low output scenarios from the 1982 Energy Projections were not used as they spanned a wider range of output than was generally considered by industry and, as already explained, there is no mechanism in our approach for varying SECs over a range of projected outputs or energy price levels.

13. Both sets of middle scenario in the 1982 Energy Projections assume a growth rate of 1½% in gross domestic product, but differ in the contribution of manufacturing industry to GDP; the upper set has a higher growth of industrial output (2% p.a.) than the lower set (1% p.a.). The difference is particularly marked in the heavy industries, such as iron and steel and chemicals.

14. The future trend in SEC in each subsector was estimated in the Sector Reports by taking account of various factors, viz:

- the amount of new capacity required to meet the assumed output, taking account of retirement and refurbishment of existing capacity;

- the technical potential for improving energy efficiency, in both existing and new plant;

- any known plans for investment in new plants or processes.

15. Some general conclusions relating to the diffusion of technical innovation have been identified and applied to the estimation of the rate at which industry takes up energy efficiency measures. These can be summarised as follows:

- an innovation requires an average of about 18 years to achieve 50% penetration of its potential market. However, this time can vary from 6 to 30 years for individual examples;

- the period is reduced if the innovation is highly profitable, and increased if it is of more marginal benefit;

- diffusion tends to be faster if the innovating industry is concentrated into a small number of firms or establishments.

16. The criteria used by industry for determining the cost-effectiveness of an investment have also been examined, and it has been concluded that a distinction can be made between major investments of a strategic nature and minor investments of a cost-saving nature. The former includes investment in new plant, which may result in improvements in energy efficiency as a secondary consideration. The latter would include measures specifically intended to save energy, such as improved insulation or additional heat recovery equipment.

17. The cost-effectiveness of an energy-saving measure, and the rate of its take-up, will be increased by increasing energy prices. However, it has not been possible to make detailed calculations of the effect of energy prices alone on the uptake of energy saving measures. This is because:

- calculations of cost-effectiveness are very dependent on specific circumstances. It is therefore difficult to generalise from individual case studies;

- data on costs and performance of processes are often commercially confidential;

- the precise relationship between the profitability of an innovation and its rate of diffusion is not known.

Furthermore, some improvements in energy efficiency, such as those resulting from management measures often described as 'good housekeeping', require little or no capital investment, while others can occur as subsidiary benefits from investment undertaken for other reasons, such as replacement of obsolete plant or the introduction of a new process technology. In such cases, any influence of energy prices would be indirect and relatively minor.

18. For each of the various energy saving measures in each subsector, the assessment of cost-effectiveness is dependent on finely balanced alternative options, the outcome of which requires judgements to be made in many cases. However, these judgements are based on the detailed understanding of the technologies involved, set out in the sector reports. Furthermore, they are made with the assistance of contacts in the industries concerned. Nevertheless, there are substantial uncertainties attached to estimates of future energy saving, which are discussed in the text.

Findings of the Study

19. It has been estimated that the energy savings in 2000 resulting from improvements in energy efficiency could be 21-25% of the energy consumption which would otherwise have been projected if no change in the 1980 specific energy consumption values were assumed. The lower value corresponds to the low output scenario, and the higher value to the high output scenario.

20. Figures I and II show the total energy savings in each industrial sector arising from the projected improvements in energy efficiency in each scenario, apportioned according to the different categories of conservation measure. Four categories are defined as follows:

- management measures, which require little or no capital investment;

- additional equipment measures, which require investment in measures such as insulation or waste heat recovery, and are solely intended to save energy;

- replacement equipment measures, in which investment in new plant to replace obsolete plant or increase capacity results in an improvement in energy efficiency as a subsidiary benefit;

- new process technology, which involves the adoption of a radically new process, possibly involving a change in raw material or product.

21. Of these four categories, additional equipment measures make the largest contribution, accounting for about 1/3 of the overall improvement in energy efficiency in the high scenario, and slightly more in the low scenario. Replacement equipment measures account for just under 1/3 of the improvement in the high scenario, and about 1/4 in the low scenario; this is because lower output would require less investment in new and replacement plant capacity. Management measures account for about 1/4, and new process technologies about 1/10, of the improvement in both scenarios.

22. The overall improvement in energy efficiency is greater in the energy intensive sectors than in the energy non-intensive sectors. For example, for 2000 in the high scenario, the energy consumption in metal manufacturing is projected to be 181 PJ, which is 33% lower than it would otherwise be if there were no change in the SEC from the 1980 values, whereas for engineering the improvement in energy efficiency is only 15%. The corresponding improvements in the low scenario are 26% for metal manufacturing and 15% again for engineering.

23. Energy Paper 32 ('Energy Conservation Research, Development and Demonstration') assessed the overall technical potential for energy savings in manufacturing industry to be 29% of total energy use. Thus the present assessment of an actual uptake of 21-25% by 2000 is within the earlier assessment of technical potential, and implies that a substantial proportion of that potential should be realised.

24. The 1980 total energy consumption for manufacturing industry determined by this study, 1,607 PJ, compares well with the value of 1,631 PJ reported in the 'Digest of UK Energy Statistics'. However, there are significant discrepancies in the data at the sectoral level. It should be noted that the two sets of data are obtained from different sources. The 'Digest' data was obtained from the energy supply industries, whereas the data in the present study was obtained from the energy consuming industries. Thus, for example the energy consumption of the Iron and Steel industry in 1980 was reported as 302 PJ by the 'Digest', but 266 PJ by the Iron and Steel Statistics Bureau. Similar discrepancies exist between 'Digest' data and the 1979 Purchases Inquiry.

25. The energy consumption of manufacturing industry in 1980 was 1,607 PJ. In a high output scenario, in which output grows at 2% per year, energy consumption of manufacturing industry increases to 1,820 PJ by 2000. This is 25% lower than it would be if there were no improvement in energy efficiency. In a low output scenario, in which output grows at 1% per year, energy consumption falls to 1,580 PJ by 2000.

26. For the reasons given in paragraph 12, a full comparison with the 1982 Energy Projections cannot be made as the findings relate only to one aspect of the Projections - the projected improvement in industrial energy efficiency. Where comparison is possible the estimates of total energy consumption in 2000 are in good agreement with the 1982 Energy Projections. In the high scenario, the present projection is 4 PJ lower than the YU scenario and 22 PJ lower than the BU scenario. In the low scenario, the present projection is 24 PJ lower than the YL scenario and 53 PJ lower than the BL scenario. These differences are less than 4% of the total energy consumption and well within the margin of uncertainty when looking so far ahead.

27. The study suggests that the increase in coal use to 2000 might be less than in the 1982 Energy Projections and that the share of natural gas in energy demand might remain relatively stable. However, these conclusions must be regarded as extremely tentative given the great uncertainty concerning the effects on them of price and output, which are not analysed in this study. The main value of the study lies rather in the detailed information which provides a basis for estimating future improvements in energy efficiency in industry. As more information becomes available, these estimates can be improved. Nevertheless they remain estimates only; they are not forecasts or targets.

CONCLUSIONS

28. In a detailed disaggregated analysis of energy use in UK manufacturing industry, this study has identified considerable improvements in recent years in the efficiency of energy use in energy intensive sectors, and traced the underlying technical changes responsible for them. In the energy non-intensive sectors, the trends in energy efficiency are less clear.

29. Improvements in energy efficiency are due to a number of causes, some of which stem directly from energy conservation measures. However, other factors can indirectly contribute to improvements in energy efficiency. These include:

- the replacement of old inefficient plant,
- product and process changes induced by international competitive pressures changing consumer demands, or advances in technology.

The extent to which these factors are likely to contribute to further improvements in energy efficiency have been assessed in two scenarios of future output. It is concluded that an improvement in energy efficiency of 21-25% can reasonably be expected to occur by 2000. This is compatible with the 'technological potential' of 29% identified by Energy Paper 32.

30. Discrepancies between the 'Digest of UK Energy Statistics' and other sources of data used in this study require further investigation.

31. The study does not purport to provide 'alternative' projections of energy use. Rather it looks at the basis for one aspect of such projections, the improvement in the efficiency of energy use. Where comparisons are possible, and within the limitations of the study, our findings provide some

technical support for the Department's Energy Projections of industrial energy demand.

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32. Drafting of this report has been carried out within the Chief Scientist's Group of ETSU (Dr R G Derwent, Group Leader). The principal contributors to the various parts of the report were as follows:

Volume I	Dr K F Langley
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Food, etc.	Mr R Hardcastle and Mr A V Ward
Engineering	Mr A V Ward
Textiles	Mr A V Ward

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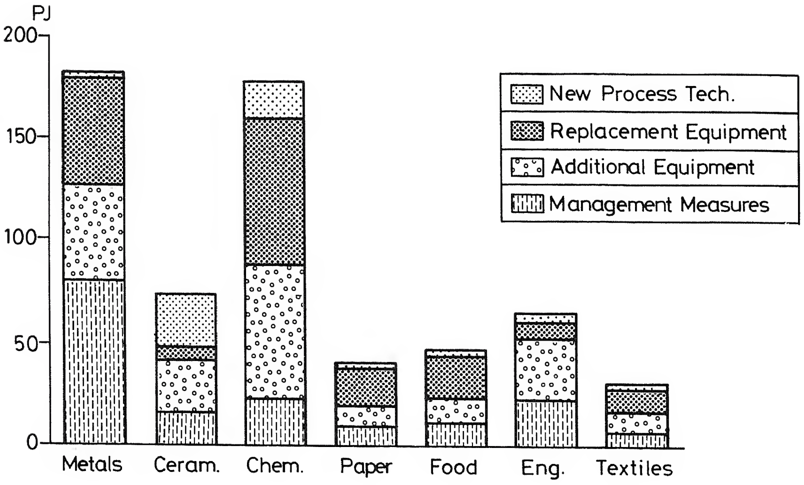

FIGURE I: Energy Saving by Category of Energy Efficiency Measure: High Output Scenario

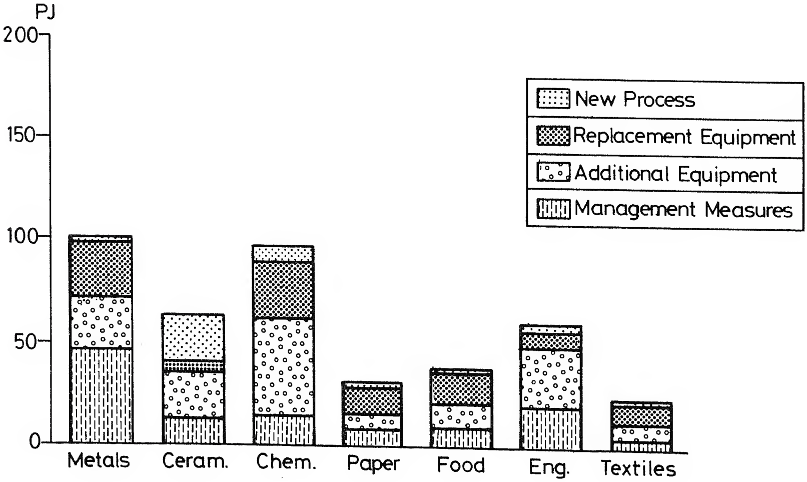

FIGURE II: Energy Saving by Category of Energy Efficiency Measure: Low Output Scenario

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References

Annex 1 Publications in the Energy Audit Series

2 Publications in the Industrial Energy Thrift Series

3 Organisations contacted during the preparation of this report

4 Tabular Presentation of Results

1. INTRODUCTION

1. In the ten years since the first oil crisis there have been a number of studies of industrial energy use and the potential for energy conservation in industry. These address a number of separate, but related, questions:

- how is energy used by industry at present?
- how much energy could be conserved?
- what progress has been made in improving the efficiency of energy use?
- what factors influence the adoption of energy conservation measures?

There has, however, been relatively little work done on assessing the likely future uptake of energy saving measures.

2. This study has therefore been commissioned by the Department of Energy to draw together the considerable body of information which is now available, to form as comprehensive as possible an analysis of future industrial energy efficiency in the UK.

3. The objectives of the study have been defined by the Department of Energy as follows:

- to assess the economic potential for improving energy efficiency through the adoption of
  - (a) best practice, using existing technologies, and
  - (b) new technologies which are expected to become cost-effective at some future date;
- to estimate the likely uptake of these measures through to the year 2000;
- to compare the findings with the Department of Energy's own 1982 Energy Projections [ref 1] and the earlier assessment of energy conservation potential in Energy Paper 32 [ref 2].

Note that the objectives exclude taking account of the impact of Government programmes: the study was set up before the Secretary of State created the Energy Efficiency Office, and the climate in which the research took place was - to the extent that the Energy Efficiency Office's programmes have been successful - less conducive to improving energy efficiency than the present climate.

4. Projections of future specific energy consumption are very sensitive to changes in output, which are in turn determined by the GDP growth rate and structural changes in the economy. Estimates of future output in the present study have been derived from sample projections of output in the 1982 Energy Projections. However, it should be noted that this study is concerned with

assessing the likely uptake of energy saving measures and the impact of technical change and not with preparing projections of energy demand.

5. In Energy Paper 32, [ref 2] it was estimated that about 30% of the energy used by industry could be saved through conservation measures. However, that estimate was confined to 'technological potential', defined as the energy saving which can be identified as technically feasible and which seems quite likely to be achieved over a long period of time. No attempt was made to assess the economic cost-effectiveness of the various measures identified, nor to estimate the rate at which they might be implemented.

6. For individual industrial sectors, detailed analyses of energy use and assessments of the opportunities for energy savings have been published in reports in the Energy Audit Series [ref 3] and the Industrial Energy Thrift Studies [ref 4]. Both of these series of reports have been used in the present study to provide a detailed sectoral analysis of the scope for energy savings. Where necessary, additional data have been collected on the industry's prospects and on other issues such as international competition which may influence the rate of technical change. The results of studies are presented in Volume II of this report and address the following sectors of manufacturing industry:-

- metal manufacturing,
- ceramic materials,
- chemical industry,
- paper, printing and publishing,
- food, drink and tobacco,
- engineering and allied industries,
- textile, leather and clothing industries.

7. Any measure which can cost-effectively be taken to reduce the energy consumption per unit of output can be described as an energy conservation measure. This might be a simple measure of improved operational procedure, which costs nothing; or it may involve a capital expenditure on additional equipment such as insulation or waste heat recovery; or it may involve investing in a completely new process, perhaps one which could not only reduce energy costs, but improve labour productivity and product quality as well. All of these measures reduce energy requirements per unit of output.

8. Although it is self-evident that higher energy prices will stimulate the adoption of energy saving technologies, the relationship between the uptake of energy conservation measures and energy prices is not a simple one, especially in the industrial sector. It was not possible in this study to investigate the effects of alternative future paths for energy prices on energy efficiency in industry. Energy conservation may involve technical change, and will be subject to the same factors which drive all technical change. However, the mechanism of technical change is complex and the factors which influence it are not limited to energy considerations.

9. In this study, we are concerned with all improvements in the efficiency of energy use. We treat energy efficiency in terms of definable parameters relating energy consumption to output, and we adopt a disaggregated technological approach to assess the improvement which can be expected to occur in energy efficiency in each sector and subsector of industry based on technical feasibility and economic cost-effectiveness.

10. In taking a disaggregated approach, we have divided industry into seven sectors and 44 subsectors which are sufficiently homogeneous to allow a detailed technical description of the use of energy at the disaggregated level. The structure of the disaggregation used was determined largely according to well-recognised definitions of separate industries for which there is a source of relevant data. Thus, industries like iron and steel, bricks, cement, etc. constitute natural entities and have organisations to represent them. In other cases, such as engineering or textiles, the boundaries and levels of sub-division are less obvious.

11. Detailed economic appraisal of the cost-effectiveness of energy saving technologies and the effects of future real increases in fuel prices has been difficult to achieve, because of the complexity of the issues involved. Similarly, the rate and extent of uptake of specific measures is a source of considerable uncertainty. In many instances, it has been necessary to make simplifying assumptions about cost-effectiveness and uptake, based partly on general considerations and partly on informed judgements supplied by industry sources. This is a highly uncertain area with many complexities. It has not been possible in a study of this form to carry out detailed appraisals of the cost-effectiveness of individual energy efficiency measures on the likely rate of take-up. Where assumptions are made in the present study these are clearly stated, and where judgements have been applied the extent of consultation is generally indicated. Considerable uncertainty must still remain for further studies to address.

12. In Chapter 2, we discuss the general factors which influence improvements in the efficiency of energy use in industry. Chapter 3 describes some of the various methods which have been used in the past to analyse energy demand, distinguishing between the econometric approach used in the Department of Energy's own projections and the 'bottom-up' approach used in the present study. The detailed methodology of the present study is set out in Chapter 4. In Chapter 5, we describe the structure of the disaggregation method, and discuss the pattern of energy use in the various sectors and subsectors. In Chapter 6 we discuss the technologies which are available for improving the efficiency of energy use. In Chapter 7 we set out our findings and compare with other studies.

2. BASIC CONCEPTS

13. In this chapter, we discuss various technical and economic concepts relating to energy use in industry. First we define what we mean by the terms 'energy conservation', 'energy efficiency' and 'energy intensity'. We discuss how the efficiency of energy use can be quantified. The relative importance of energy to different industries is compared in terms of various ratios describing energy intensity. Then we distinguish between various categories of measures for improving efficiency of energy use. A brief account is given of empirical studies from the literature into the mechanism by which technical innovation diffuses into industries, in order to provide some insights into the rate of uptake of energy efficiency measures. Finally, the economic criteria applied by industry to investment in energy conservation are briefly discussed. The application of these various concepts to the methodology of the present study is described in Chapter 4.

DEFINITION OF TERMS

14. In our studies of the various sectors of manufacturing industry in Volume II of this report, we have observed a gradual reduction in the amount of energy used per unit of output, due to improvements in the efficiency of production plant and processes. The reasons for this improvement are complex. In some cases it has been brought about by the closure of older, less efficient plants to reduce capacity; in other cases it is the result of measures taken directly to reduce energy consumption. Energy intensive industries, in which energy costs are a large proportion of overall production costs, tend to respond more sharply to increases in energy prices.

15. 'Energy conservation', 'energy efficiency' and 'energy intensity' are widely used terms which address these complex issues. They are, however, often loosely defined and we have found it necessary to set out our own definitions.

16. Energy Conservation To some extent, the term energy conservation can imply an intention to save energy as the primary motive for undertaking measures which save energy. This confusion of motive with the measure and its end result is too restrictive to allow us to develop a convincing description of the impact of technical change on the industry sectors which we have studied. Hence we have tended to avoid the use of the term 'energy conservation'.

17. The motivation for undertaking specific energy saving measures is the cost saving and other improvements which result. Hence, an energy conservation measure will only be implemented if it is anticipated to be cost-effective. The cost-effectiveness of a measure is determined by comparing its cost and the financial value of the energy savings and other improvements with some criterion such as a required internal rate of return or, more usually, a required simple payback period. Clearly, the cost-effectiveness of a given measure will improve if energy prices rise in real terms. However, if short payback times are required the effect of rising fuel prices may be limited.

18. In practice, however, it is often difficult to relate cost-effectiveness to energy prices directly. Other factors may be involved.

For example, a technical modification to a process may improve product quality or productivity as well as energy efficiency. Hence, energy saving may be only a secondary benefit from a measure taken primarily for other reasons. Conversely, an energy saving measure may adversely affect product quality or productivity, perhaps to an unquantifiable extent.

19. In this study, we are concerned with identifying scope for cost-effective improvements in the efficiency of energy use, irrespective of why or how they come about. Any technical measure which leads to an improvement in energy efficiency is considered to be an energy conservation measure. We see energy conservation as synonymous with energy efficiency and in the rest of the report the terms are used interchangeably.

20. Energy Efficiency 'Energy efficiency' is a convenient phrase for describing the concept of economic efficiency of energy utilisation. However, problems arise when we attempt to define a common basis for measuring it. 'Energy efficiency' has a precise technical meaning when applied to a machine: it is the ratio of the output energy to the input energy. For an industrial process, however, there is no energy output as such. Energy efficiency must then be defined as energy input relative to some absolute standard such as a theoretical minimum energy requirement. A definition on this basis is, however, specific to the particular process involved.

21. In order to make comparisons across an industry sector, various ratios can be defined, such as GJ/tonne or MJ/litre, which measure energy consumption per unit of output. Using these ratios to measure the efficiency of energy utilisation is analogous to measuring the energy efficiency of a motor car in terms of miles per gallon.

22. For a given product or process, the energy consumption per unit of physical output is called the 'specific energy consumption' (SEC). For a single uniform product, such as cement, the SECs of different individual plants or processes can be compared directly. Similarly, for one plant, the SEC in one period of time can be compared with the SEC in another period of time. SEC is thus a measure of energy efficiency.

23. For an industry as a whole, an average specific energy consumption, SEC_{AV}, can be calculated. Changes in the SEC_{AV} are related to technical changes within the industry, such as the replacement of an old, inefficient plant by a new one with a lower SEC.

24. Where more than one product is produced by an industry, then a composite SEC can be calculated, which is an average of the SECs of the individual products, weighted by output. However, care mut be taken when comparing composite SECs from different time periods, because any differences will not only reflect changes in energy efficiency, but also any structural changes in output. For example, in the dairy industry, a shift in the market from liquid milk to cheese would affect the composite SEC_{AV} for the dairy industry, because liquid milk and cheese have different SECs associated with their manufacture.

25. For an industry which produces a very diverse range of products, it is not always possible to use a physical measure of output to calculate the SEC. This applies particularly to the engineering and textile industries, and

parts of the food and chemical industries. In these cases, output is measured in other terms such as gross monetary output or numbers of employees. Thus, energy consumption per unit of gross monetary output or per employee is used as a proxy for the physical SEC for the purposes of comparing energy efficiency.

26. The physical measures of SEC are more easily related to technical improvements in energy efficiency than the proxy measures. They are however, of little relevance for comparisons between different industries. For example, cement and biscuits have approximately the same physical SEC (ca. 7 GJ/tonne). However, in terms of output value, the SEC for cement (186 MJ/£ gross output) is considerably higher than for biscuits (6.9 MJ/£ gross output). Energy consumption is therefore a more important consideration for a cement manufacturer than it is for a biscuit manufacturer.

27. **In this report, we measure energy efficiency in terms of specific energy consumption, defined as energy consumption per unit of physical output. Where physical output is not measurable, then gross monetary output or numbers of employees is used as a proxy.**

28. Energy Intensity The relative importance of energy consumption to a given industry compared with other industries is called the 'energy intensity'. However, gross monetary output involves double-counting of products traded within an industry. Furthermore, industries differ greatly in the costs of their raw materials. These factors distort comparisons of energy intensity between industries. To minimise distortion, energy intensity can be measured in terms of energy per unit of net monetary output, or added value, which is the difference between the value of the goods produced and the materials and energy purchased by the industry.

29. Another comparison of energy intensity can be based on the ratio of energy purchases to total purchases. This ratio highlights the distortion caused by high raw material costs. Thus, for example, in the edible oil and fat industry, energy accounts for only 2.5% of the total purchases, compared with 28% for the glass industry. In terms of net monetary output, however, the two industries have similar energy intensities (64 and 86 MJ/£ net output, respectively). Thus, any improvement in energy efficiency in the oils and fats industry may have little effect on the total purchases of the industry, but could be very significant in terms of added value, and therefore profit.

30. In this report energy intensity refers to any ratio which describes the relative importance of energy costs to an industry. Note that the same ratios can be used to describe both energy efficiency and energy intensity in different contexts.

CATEGORIES OF MEASURES FOR IMPROVING ENERGY EFFICIENCY

31. As we have already noted, improvements in energy efficiency can occur in a variety of ways. In order to understand better the relative impact of the various causes, we define four categories of measures which can improve energy efficiency:

- management measures;

- additional equipment measures;
- replacement equipment measures;
- new process technologies.

32. Management measures are measures which can be taken through management action with little or no capital expenditure. They include' good housekeeping' measures such as better control of heating and lighting, better scheduling of energy intensive processes, switching off equipment when it is not in use and improved maintenance of boilers, furnaces and steam distribution systems.

33. Additional equipment measures involve the investment of capital on energy saving measures such as insulation and waste heat recovery. These measures can either be retrofitted to existing plant or included on new plant as 'optional extras'. Generally, they have little or no effect on product quality or throughput; their sole purpose is to save energy. Consequently, they have to be justified by the value of the energy saved in proportion to the capital cost.

34. Replacement equipment measures involve the replacement of worn-out or obsolete plant with new plant of modern design. Any improvements in energy efficiency which result are not the sole reason for undertaking the measure; the equipment needs to be replaced anyway. The justification might include the reduction in maintenance costs, improvement in product quality and increased throughput, with energy saving providing an incidental benefit. Nevertheless, such measures can make a significant contribution to improvements in energy efficiency.

35. New process technologies are somewhat similar to replacement equipment measures, but involve more radical changes in the process concerned, for example the change from a wet to a dry process in cement making, or continuous casting in steel making.

THE DIFFUSION OF INNOVATION

36. A new technology is rarely (if ever) adopted simultaneously by all the firms which could benefit from it. Usually, a new process or product is commercialised initially by one firm, the innovator. When its superior qualities become generally recognised, other firms within an industry will seek to adopt it; the innovation thus spreads throughout the industry by imitation. This process is known as 'diffusion' and has been the subject of extensive research aimed at understanding the general factors which determine its rate.

37. The rate of penetration of an innovation into its potential market as a function of time can typically be described by a curve of the type shown in Figure 1, known as a 'logistic' curve. The initial rate of diffusion for innovation is slow, as the innovative firm or firms evaluate the innovation, and information about it remains fairly restricted. Gradually, the imitators learn about the innovation and adopt it. The incentive for the imitators is the competitive pressure from adopters, which increases as penetration increases. Also, as experience of the process accumulates the risks of adoption fall. Thus adoption by the imitators builds up into a surge, or

bandwagon effect. However, some firms are more resistant to change, or have less need of the innovation, and do not adopt so the rate of penetration eventually slows down again. Hence the S-shape of the logistic curve.

38. In a pioneering study of diffusion of innovation, Mansfield [ref 6] used the logistic model to examine retrospectively 12 innovations in four industries (coal, iron and steel, brewing and railways) and found that the rate of diffusion of an innovation is a linear function of:

- the profitability of installing it (the more profitable, the faster the rate of adoption),

- the size of the investment required to install it (the larger the investment, the slower the rate of adoption).

The more profitable an investment is expected to be, the more likely it is that the expected return will compensate for the risks involved. For equally profitable investments, risk aversion is likely to increase with the size of the investment, which will slow down the rate of diffusion.

39. Mansfield's model, and subsequent developments of it, have been used successfully for forecasting market penetration of new technology in a number of fields, such as aviation, petroleum refining and electricity generation. Provided that an estimate can be made of the total market size, and there is some information about the time dependence of the diffusion, a penetration curve can be constructed. This can be based on early information from the market on the time taken to achieve, say, 10% of the total estimated market. Alternatively, it can be estimated by reference to the known diffusion curve for some suitable analogue.

40. In a recent study of innovation in UK industry, Davies [ref 7] distinguished between two different kinds of innovation:

- group A innovations are technologically simple, relatively cheap and produced off-site;

- group B innovations are more sophisticated, expensive innovations which are installed on a one-off basis on the adopter's site.

Davies develops a theoretical model to show that diffusion of group A innovations should follow a cumulative log normal curve, and group B innovations should follow a cumulative normal curve (Figure 2).

41. Davies' model is based on assumptions about the behaviour of firms in decision making, taking account of a firm's expectation of the payback from the innovation meeting the firm's criterion for payback. Probability distributions are used to describe the probability of a firm adopting an innovation at a given time. It is assumed that firms of different size will have different expectations of how profitable any innovation would be; size of firm is thus a major explanatory variable within the model.

42. The shape of the diffusion curve differs between the two groups of innovation, because the relatively simple group A innovations would tend to diffuse more rapidly in the early years than the more complex and expensive group B innovations, for which there is an initial learning period.

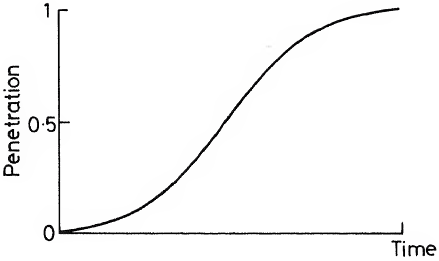

FIGURE 1: The Logistic Epidemic Curve

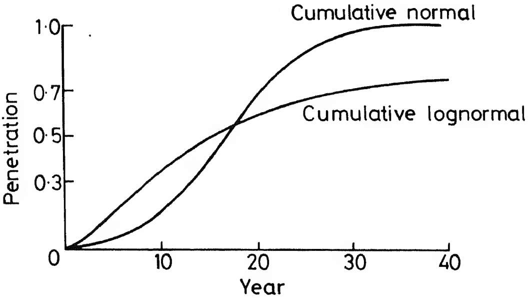

FIGURE 2: A Comparison of 'Typical' Cumulative Lognormal and Normal Diffusion Curves

43. Davies tested his model against data for 22 innovations introduced into UK industry between 1948 and 1962. These included:

- special presses, foils and synthetic fabrics in the paper and board industries;
- automatic track lines in car manufacture;
- basic oxygen steel making, continuous casting and vacuum degassing processes in the iron and steel industry;
- tunnel kilns in the brick industry.

Eight of the innovations were classified as group A, seven as group B, while the remaining seven were unclassified, having characteristics in common with both groups.

44. All but four of the 15 classified innovations fitted the diffusion curve appropriate to its classification, and for three of those four ancillary evidence suggested that the difference between actual and predicted behaviour could be explained within the framework of the model. In the case of the seven unclassified hybrid innovations, for which the model gave no prediction of the diffusion behaviour, the empirical data could be fitted to either the group A or group B curves. Thus, in all but one of the 22 innovations, the observed data gave a better fit to one of the model curves in Figure 2 than to the Mansfield form of logistic in Figure 1. Note that the cumulative normal (group B) and logistic curves are similar in shape. Both are symmetrical about a point of inflection at 50% penetration. However, the logistic curve has relatively longer tails.

45. The time lapse between the invention of a new technology and its commercial introduction is very variable, and can depend on a number of factors specific to the technology. For example, it may take one or more stages of prototype development to overcome technical difficulties or reduce costs to an acceptable level. Even when a successful prototype has been developed, it may take several years of trouble-free operation before the market is prepared to accept the innovation as fully commercial. To overcome the difficulties arising from the variability of this initial period, Davies defines the commencement of the diffusion process as one year prior to the date when market penetration reaches 1%.

46. The average time lapse for 50% diffusion was about 18 years for both group A and group B innovations. However, although group A innovations exhibit a more rapid take off than group B, penetration soon decelerates in the former case, while it continues to accelerate in the latter case. Thus group A innovations tend to diffuse more raidly in the early years, but in the long run they diffuse more slowly than group B innovations, and are more likely to never be adopted by 100% of the potential market. This is interpreted by Davies to indicate that competitive pressures make major process changes unavoidable for all firms, whereas minor innovations are less critical to the competitive position of adopting firms and may be obscured by other productivity differences between firms. It also implies that for group A innovations the initial estimate of the size of the potential is exaggerated.

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47. Davies found a considerable range in the observed speed of diffusion, especially for group A. Thus three group A innovations, and one group B, achieved 50% penetration within about six years of first introduction, compared with the average of 18 years for both groups; others required as long as 30 years.

48. Like Mansfield, Davies found that the speed of diffusion depends on the profitability of the investment. This is to be expected on an intuitive basis, since the more profitable innovations will exert more competitive pressure on non-adoptors. Unlike Mansfield, however, Davies did not find any tendency for the more expensive innovations to diffuse more slowly. This discrepancy in the findings of the two studies may be due to the distinction made by Davies between group A and B innovations. Thus capital outlay may be significant in determining the functional form of the diffusion curve but not its slope.

49. Although previous studies of diffusion provide evidence to suggest that the rate of growth in an adopting industry may have an important influence on the diffusion rate, Davies found only a marginal positive influence.

50. Davies found that the larger firms within an adopting industry are more likely to adopt an innovation sooner than the smaller firms. This does not imply that larger firms are more progressive than small firms. Diffusion is fastest for innovations in industries where there are a small number of equal sized firms. Information exchange and contact with innovation suppliers may be less frequent and effective in industries with large numbers of firms. Furthermore, diffusion within a large firm is likely to be more rapid than among a number of small firms.

51. Given the number and complexity of the factors which determine the diffusion of energy efficiency measures, it is not possible to give a rigorous analysis for each measure and each industry sector. Rather, we have drawn on the empirical evidence from the studies of diffusion of industrial innovation described above, to provide a simplified penetration model.

52. **The empirical results which have been applied to the description of the diffusion process in the sector reports in Volume II can be summarised as follows:**

- **an innovation will on average require about 18 years to achieve 50% penetration of its potential market, but the range can be from 6-30 years.**
- **the period will be shorter if the innovation is found to be highly profitable, and longer if it is of more marginal benefit.**
- **diffusion will be faster if the industry taking up the innovation is concentrated into fewer establishments owned by fewer firms.**

Note, however, that these empirical studies do not provide any indication of the effect which the rate of economic growth might have on the rate of diffusion of innovation. Nor can they take account of changes in external factors such as a new and effective Government campaign to get industrialists to improve their energy efficiency.

CRITERIA FOR COST-EFFECTIVENESS

53. The choice of criteria for determining cost-effectiveness of an energy saving measure is complex. It will depend on:

- the nature of the energy saving measure, e.g. whether a minor modification retrofitted to an existing plant or a major change in the design of a new plant;
- the nature of the industry, e.g. a high growth, high technology industry competing in international markets or a traditional industry which has little competition from imports;
- the general economic outlook. New investment might be expected to be favoured by a period of growth rather than recession.

54. Energy conservation investments are generally required to have short payback periods. In the recession of 1981-82 paybacks of less than two years were being sought, reflecting the uncertain prospects for industries with chronic over-capacity. However, even in relatively buoyant economic circumstances, 2-3 year payback periods are sought for many energy conservation investments.

55. On simple economic arguments, these payback periods appear to be much shorter than they ought to be. For example, a typical industrial company might use a real discount rate of 10% and a capital recovery period of 10 years for investment planning. The discount rate represents the opportunity cost of capital, while the capital recovery period is determined by the planning horizon to which a market for the company's products can realistically be projected. These parameters give an amortisation factor of 0.163, which is equivalent to a simple payback period of 6.1 years (i.e. the reciprocal of the amortisation factor). However, for products with a short product life-cycle or uncertain business prospects, the capital recovery perod might be only five years; the required simple payback equivalent to a 10% discount rate would then be only 3.8 years. Conversely, if there is confidence about the long term future of the plant or markets, longer capital recovery periods might be permitted.

56. An indication of what firms actually do is given in a study carried out by Armitage-Norton Consultants Ltd [ref 8] for the Department of Energy, in which the extent to which industry is investing in energy conservation was assessed, and barriers to investment in energy conservation were identified. The findings of the study were based on evidence provided by 94 companies interviewed by telephone and 29 companies interviewed in depth in a field survey. The surveys found a wide range of achievement of energy savings, from none to over 50% of total energy use, with a mean of 10% of total energy use. Half of the sample had achieved less than half of the potential savings open to them; the remaining cost-effective potential (measures with payback periods of less than three years) would save a further 14% of the current total energy use. However, the survey did not include any energy intensive industries, which would be expected to be more energy conscious than the majority of companies.

57. Armitage-Norton suggest that the investment criteria applied by companies to different kinds of investment tend to discriminate against

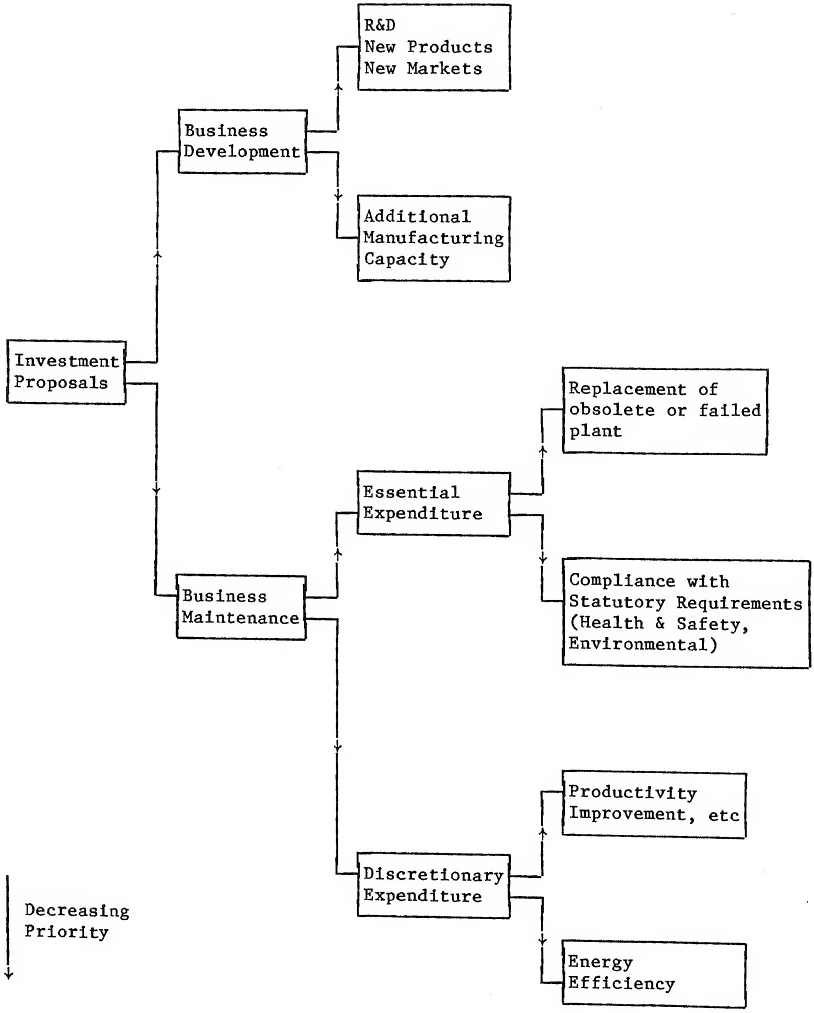

R&D
New Products
New Markets
Business Development
Additional Manufacturing Capacity
Investment Proposals
Replacement of obsolete or failed plant
Essential Expenditure
Compliance with Statutory Requirements (Health & Safety, Environmental)
Business Maintenance
Productivity Improvement, etc
Discretionary Expenditure
Decreasing Priority
Energy Efficiency

FIGURE 3: Classification of Investment Proposals

energy conservation measures. Large companies plan their capital investment by first setting a capital budget which limits the total amount of expenditure permitted, and then classifying individual investment proposals according to a system such as that shown in Figure 3. Most energy conservation projects examined by Armitage-Norton are categorised as discretionary expenditure, the primary objective of which is to reduce the company's production costs within an existing plant or process. Whilst cost-saving projects should result in increased profit, they are not essential for the continued operation of the plant, and they do not contribute to the long term future profits which are sought from strategic investments. Hence, cost-saving discretionary investment is accorded low priority in the allocation of the capital budget, and only those proposals with short payback periods can compete successfully with proposals which have higher priority. Furthermore, Armitage-Norton found that, within the category of discretionary expenditure, there is a preference for labour-saving investments over energy-saving ones.

58. Additional evidence for this hierarchy of investment priority can be found in Davies' study of innovation, discussed earlier (cf. paragraph 33). The simple payback periods for the innovations studied by Davies range from less than one year to 11 years. For class A (minor) innovations, the average was two years whereas for the class B (major) ones it was 4.3 years. However, improvements in energy efficiency are not necessarily confined to the class A investments, which can be compared with the discretionary category identified by Armitage-Norton. For example, the Basic Oxygen process for steel-making is a class B innovation for which Davies quoted a payback period of six years; similarly, Davies found that tunnel kilns in brick-making have a payback period of 5.6 years. These are both innovations which involve major strategic investment decisions in energy intensive industries.

59. The Armitage-Norton study was confined to energy non-intensive industries, in which energy conservation measures tend to involve minor process modifications with limited impact on the overall cost-competitiveness of the companies concerned. Thus it is not surprising that they found that energy conservation measures are placed in the discretionary category, for which a two year payback requirement is the norm. In energy-intensive industries, however, an energy conservation measure which involves a major process change is likely to be treated as a strategic investment for which payback periods of up to six years are acceptable.

60. For the purposes of the present study, therefore, the following criteria are adopted for determining whether or not an energy saving measure is cost-effective:

- for major changes to an energy-intensive process, a simple payback of 4-6 years is required;

- for minor changes to an energy non-intensive process, a simple payback period of 2-3 years is required.

These criteria are applied with some flexibility in the sector reports, because there is often considerable difficulty in obtaining precise economic data for determining the payback of individual measures. Furthermore, regard must be paid to the particular circumstances surrounding a particular technology or industry.

3. APPROACHES TO INDUSTRIAL ENERGY DEMAND ANALYSIS

61. The essential feature of the methodology used in this study is that it builds up an account of energy use in industry as a whole by considering how energy is used in the manufacture of individual products or groups of products. This so-called 'bottom up' approach involves a technical analysis of the various sectors and subsectors of industry, which is quite different from the econometric approach to energy modelling, sometimes known as a 'top-down' approach. In this chapter, we discuss the main features of the different approaches to energy demand analysis, including their relative advantages and disadvantages.

ECONOMETRIC MODELLING

62. Econometric modelling of industrial energy demand involves estimating statistical relationships between useful energy consumption (E) (after taking account of end-use efficiency) and explanatory variables such as industrial output (Y), real energy prices (P) and ambient temperature (T), using equations of the form:

$$E = A.Y^{\alpha}.P^{\beta}.T^{\gamma},$$

where A, α, β and γ are constants obtained by analysis of historical data. This equation can be subdivided into shares for the main individual fuels. An allowance for time-lags between changes in the explanatory variables and subsequent changes in the energy demand is also included in the equations. A detailed account of the equations used in the Department of Energy's energy demand model is given in reference 9.

63. An econometric model takes account of changes in the efficiency of energy use in two ways. Firstly, even if fuel prices are constant in real terms energy demand tends to rise less quickly than output, mainly as a result of technical change, new equipment generally being more energy efficient than the equipment it replaces. Secondly, if real fuel prices rise, then energy demand will tend to fall for a given level of output. In the latter case, other inputs (such as capital for additional insulation or improved boiler controls) are substituted for energy. The 'non-price' and 'price' components of increasing energy efficiency are incorporated into the energy demand equation through the values of the indices α and β.

64. Equations of the above type give a good fit to historical data. When they are used to project future energy demand there is an implicit assumption that the coefficients will not change in the future. This, in turn, implies that the past rate of technical change and price elasticity of energy demand will not change. Given the other uncertainties inherent in projecting the future - especially the uncertainty in the assumptions for economic growth and energy prices, which are exogenous to the model - any changes which are likely to take place in the value of the coefficients will have only a second order effect on the demand projections. Nevertheless, it is desirable to have some degree of confidence that the improvement in energy efficiency which is required by the econometric extrapolation is achievable in physical terms. Thus, the 'bottom up' approach is a useful complementary activity.

65. However, this approach has some important strengths. The statistical relationships do embody the responses of energy use in individual sectors to

price and output changes which have occurred over the data period of some two and a half decades. Furthermore the lag structures in the equations capture the rates of response over time to these changes and hence reflect the pace of technical change, the turnover of process plant and behavioural responses to a changing environment. Finally such models at present provide the only flexible means for exploring a comprehensive range of energy projections against a suitably wide range of alternative macro-economic assumptions about the future.

BOTTOM-UP ANALYSIS

66. Energy demand analysis based solely on a bottom-up approach would require detailed information on energy using technologies. Ideally, this would mean a complete inventory of boilers, furnaces, electric motors, etc., together with a knowledge of the production process for every product, in order to be able to calculate the energy demand for process heat and motive power. Such an inventory would include the age, life and efficiency of each item. In addition, in order to calculate the requirement for space heating and lighting in industrial buildings a complete inventory would be required giving information such as heat loss characteristics and lighting equipment.

67. If it were possible to have a sufficiently detailed data base, one could in principle make projections of future changes in the inventory, taking account of factors such as the replacement of old equipment which had reached the end of its useful life by modern, more efficient equipment, and the installation of additional capacity to meet increased demand for products. The potential for new production processes could be assessed and quantified within the model.

68. A considerable amount of research has been done in recent years to develop the bottom-up approach to energy demand analysis. For example, the Science Policy Research unit at Sussex University have recently published a survey of boilers in UK industry [ref 10] for which a sufficiently detailed data base exists. However, a data base with sufficient detail to give a complete physical description of all energy using plant, without some statistical averaging, would be extremely complex. Although such an analysis could prove valuable for important types of plant such as boilers, in practice, a rigorous quantitative model for projecting changes in the inventory is not feasible.

69. A further problem with the 'bottom-up' approach is the difficulty of quantifying the effect of energy prices on energy demand. Qualitatively, it is reasonable to assume that increases in real energy prices stimulate energy saving measures, at least in the long term. (In the short term, real energy price increases can lead to a fall in output; initially this can cause a fall in energy efficiency, because plant is operated with low load factor.) Subsequently, however, the closure of the least efficient plant results in an overall improvement in energy efficiency. The extent to which firms will substitute capital for energy can be measured in econometric terms by a price elasticity factor. In a bottom-up approach, however, it can only be examined by:

- determining the cost-effectiveness of a specific investment against some investment appraisal criterion;

- measuring the rate at which cost-effective investments are made, perhaps through some diffusion model.

The major difficulty with applying such an approach, even if the level of detail required were possible, is the lack of definitive information on the way in which industry responds to technical innovation and the profitability of changing processes. Views can be sought from those working in each industry or from researchers studying the industry in depth but the conclusions cannot be automatically adjusted to cover a range of assumptions about the future. This problem is discussed in greater detail at paragraphs 109-115.

ENERGY PAPER 39

70. Two different approaches to modelling industrial energy demand were used in the ETSU exploratory scenario, which was published as part of Energy Paper 39 [ref 11]. These were:

- separate physical models for the iron and steel and petrochemical sectors, and

- a generalised disaggregated model for seven other sectors.

The physical models related energy consumption in specific processes to the throughputs of material. Detailed consideration of the scope for introducing new process technology and shifts in the relative throughputs of different processes were included in the models. The generalised disaggregated model however, overcame the difficulty of considering throughputs of materials for a diverse range of products by relating energy consumption to indices of net output (on a monetary value added basis) for each of the seven sectors. Details of this approach were published in reference 12.

71. Process heat and motive power requirements were treated in terms of effective energy per unit of net output. Effective energy was defined as the heat supplied to a process multiplied by the relative efficiency of the energy carrier. This definition enabled different energy carriers to be interchangeable in a given application. The changes in the effective energy/output ratio for each sector were projected by estimating the effect of new process technologies, product mix, energy carrier mix and energy carrier conversion efficiency. By combining the projected effective energy/output ratio with projections for output, the useful energy demand could be calculated.

72. The energy requirements for space and water heating were expressed in terms of useful heat per unit of floor area. An index of heated floor space, modified by an index of useful heat per unit area to take account of improved insulation, etc., give a useful heat demand for each sector, which can be converted to heat supplied, using an appropriate conversion efficiency. Heat supplied to buildings and processes is allocated to energy carriers, which include steam from a central boiler or CHP plant; at this stage it is described as 'tertiary energy'. The tertiary energy requirement leads back to the secondary energy - the energy supplied to the factory gate - by taking account of central boiler and CHP plant.

73. The generalised disaggregated model is a compromise between the detailed technical description of a physical model and the extrapolative nature of an econometric model. It allows some account to be taken of the scope for structural change and technical innovation, based on informed judgements. However, its treatment of new processes and energy conservation technologies is semi-qualitative. For example, the ETSU exploratory scenario projects a 15% reduction by 2025 in effective heat per tonne of product in the ceramic materials sector, 'due largely to the introduction of dry cement processes in areas where raw materials are suitable' [ref 12, page 22]. This projection is a broad-brush summary of the large number of opportunities for improving energy efficiency in the manufacture of cement and other ceramic materials, such as bricks and glass, and involves a judgement of the rate and extent of penetration of the new technologies. Other research workers, who have used a similar methodology to construct low energy scenarios, have taken different values for the reduction in the same effective heat ratio. For example, Leach et al. [ref 13] postulate a 35% reduction, while Olivier et al. [ref 14] take a value of 73% in their A1 scenario. In doing so, they are applying different judgements, which may involve a subjective expression of their aspirations for a low energy future.

THE DISAGGREGATED TECHNOLOGICAL APPROACH

74. In order to resolve the difficulties in quantifying the effects of specific process changes and structural change within an industry sector, we have adopted a methodology which sets out more explicitly the assumptions made in determining the energy consumption of each sector. This involves a *detailed technical description* of the use of energy in disaggregated industry sectors. The level of disaggregation varies from one sector to another; it is determined by the need to specify groups of products or processes which are sufficiently homogenous to be analysed in terms of *specific energy consumption* (SEC), i.e. energy consumption per unit of output.

75. Future changes in SEC are estimated by examining the scope for improving energy efficiency through technical measures, allowing for their penetration through the sector and considering the future output levels anticipated. For each subsector of industry, an assessment of the total energy consumption at some future date can be obtained by multiplying together projections of SEC and output for the subsector. Thus, the methodology requires separate treatments of SEC and output, based on a detailed analysis of the subsector in terms of historical trends and future potential for both SEC and output. The details of the methodology are given in Chapter 4.

76. Unlike the ETSU Exploratory Scenario, the analysis is carried out in delivered energy (i.e. heat supplied) terms, rather than in useful heat terms. The latter would require an additional set of parameters on conversion efficiency for calculating delivered energy. Because of the highly disaggregated nature of the study, the additional complexity involved in such a procedure would be daunting. To avoid this, the individual SECs at the process or product level are determined directly in delivered energy terms, taking due account of any changes in conversion efficiency.

77. This approach does not permit the construction of a full set of energy demand projections. In practice SECs, which are the main output from the study, are not independent of either the level of production or the level

of energy prices. In the study it is not possible to analyse the effects of alternative fuel price paths on energy efficiency and nor were investment appraisals carried out to check the cost-effectiveness of individual energy efficiency measures or their likely take-up. The SECs shown were prepared in the context of particular assumptions about future output levels and illustrative energy demands and energy savings can be obtained by multiplying SECs by these same output assumptions. There is no mechanism in this approach for varying the SECs over a range of projected outputs or energy price levels. Nevertheless, studies of this type can provide a useful and complementary approach to considering possible future changes in energy efficiency from a technological point of view.

4. THE METHOD USED IN THIS ANALYSIS

78. In this chapter, we explain the analytical method used in the study. The main feature of the method is that it requires a detailed technical description of the way in which energy is used in disaggregated industry sectors. Figure 4 shows schematically the analysis which we have carried out. The primary aim in each sector or subsector is to estimate the realistic improvements in energy efficiency at various dates up to the year 2000.

79. Figure 4 shows that our starting point is the present pattern of energy use in manufacturing industry. This is dealt with in some detail in Chapter 5, where an account is given of:

- the disaggregation used,
- the fuel carriers considered, and
- the main categories of processes for which the energy is finally used.

This allows us to define for each sector or subsector the groups of products and processes which are sufficiently homogeneous to be analysed in terms of specific energy consumption (SEC), i.e. energy consumption per unit of output. The measure of output used varies from sector to sector, but is in physical terms (i.e. tonnes or litres) where possible. The level of disaggregation varies from one sector to another; it is determined by the availability of data, see Chapter 5.

80. The extent to which specific energy consumption has improved is determined by the progress of technical change and the uptake of energy efficiency measures. We have therefore studied the technologies for energy saving and estimated their likely uptake. Chapter 6 provides a summary of these technologies and indicates their relevance to each sector or subsector. The progress towards the more efficient use of energy in the future is measured by the specific energy conservation factor which compares the future SEC with the SEC in 1980. The remainder of this chapter describes how we have constructed estimates of future SEC values from which the results in Chapter 7 have been derived.

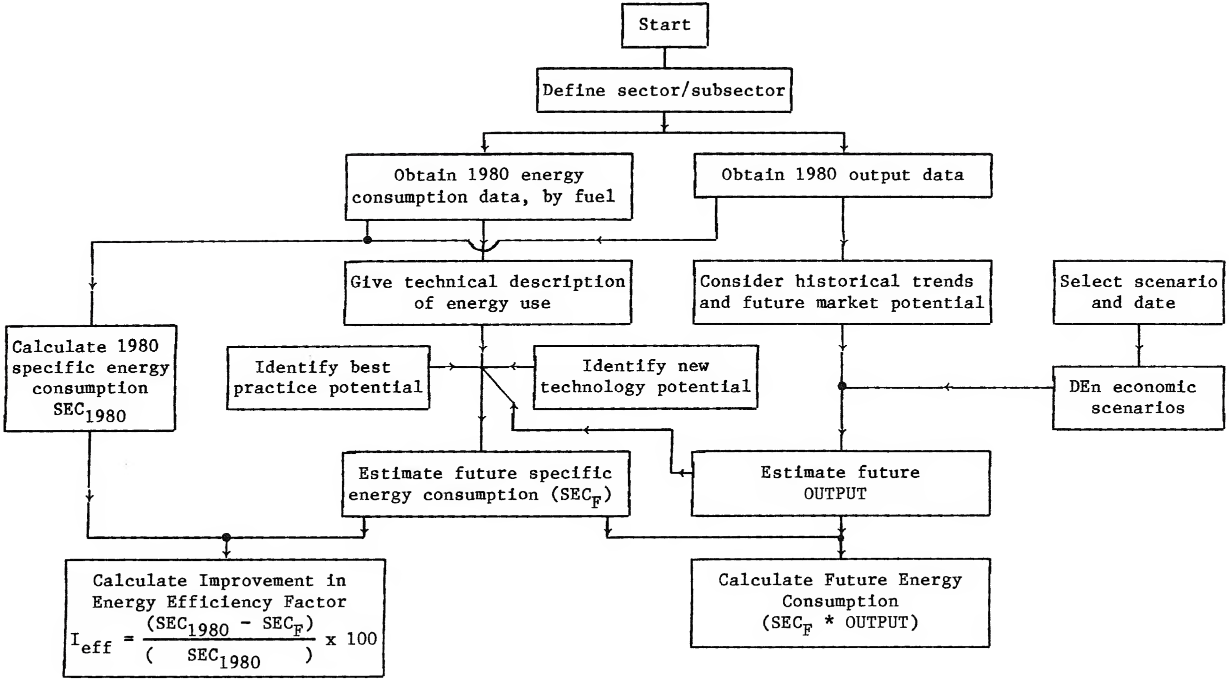
SPECIFIC ENERGY CONSUMPTION

81. The specific energy consumption is the energy consumption per unit of output. In Chapter 2 it was noted that, using different measures of output, SEC could be analysed in two ways:

- as a time-series comparison of energy efficiency within a subsector;
- as a cross-sectional comparison of energy intensity between subsectors.

Energy intensity comparisons of the subsectors provide a useful insight into the way in which energy is used in industry as a whole, and an analysis of energy intensities of the different subsectors is given in Chapter 5.

FIGURE 4: Flowchart Showing Methodology


Start
Define sector/subsector
Obtain 1980 energy consumption data, by fuel
Obtain 1980 output data
Give technical description of energy use
Consider historical trends and future market potential
Select scenario and date
Calculate 1980 specific energy consumption SEC_{1980}
Identify best practice potential
Identify new technology potential
DEn economic scenarios
Estimate future specific energy consumption (SEC_F)
Estimate future OUTPUT
Calculate Improvement in Energy Efficiency Factor
$I_{eff} = \frac{(SEC_{1980} - SEC_F)}{(SEC_{1980})} \times 100$
Calculate Future Energy Consumption (SEC_F * OUTPUT)

82. For the purposes of energy efficiency comparisons, SEC is most appropriately defined as the energy, in heat supplied terms, used to make a tonne or litre of product concerned, and is usually quoted as GJ/tonne or MJ/litre. In each subsector, the exact definition of the SEC has to be carefully stated. For example, in the iron and steel industry, where there is a number of products categorised as finished steel, such as steel strip, section or tube, it is conventional to measure output in terms of crude steel, and specific energy consumption as:

$$\frac{\text{total energy consumed}}{\text{output of crude steel}}$$

Note that although the SEC is expressed as GJ/tonne of crude steel, it includes the energy used in finishing processes, averaged across the output. Any change in the structure of finished steel output will affect the SEC; more significant, however, is the proportion of steel made by the two main production processes (basic oxygen and electric arc) and the proportion of steel scrap and pig iron used.

83. In the brick and cement industries there are also differences in raw materials and processes used to make what are basically uniform products. For each of these subsectors, a separate SEC can be determined for each process, with allowances made for future changes in the structure of the subsectors.

84. In other subsectors, such as the dairy and bakery industries, there are a number of different products, with the likelihood of a shift in the structure of the industry to higher added value products in line with future economic growth. In these subsectors, an SEC is determined for different products or groups of products (e.g. liquid milk, butter, cheese, etc.) and future market shares of the products estimated.

85. In engineering as a whole, and certain other subsectors (e.g. pharmaceuticals, and miscellaneous textiles) the range of products and processes is so diverse, that a physical measure of output is not feasible. In these circumstances, SEC is defined in terms of gross monetary output (total sales).

86. For each subsector, a number of factors must be considered in order to make projections of future SEC. These include:

- future output levels;
- energy conservation potential;
- the amount of new production capacity required to meet the future output, taking account of retirement of existing capacity;
- any known plans which the subsector has for investment;
- the rate of diffusion of technical innovation.

In the sector reports, these considerations are quantified by making a set of assumptions within a framework of technological analysis of energy consumption.

FUTURE OUTPUT

87. Because the future energy demand in industry depends on the product SEC*OUTPUT, and the SEC itself depends partly on output, energy demand is very sensitive to the level of output. It must be stressed, however, that the main objective of this study is to determine the likely uptake of energy saving measures rather than to project energy demand.

88. The future output levels assumed in this study are based on the economic assumptions used in the Department of Energy's 1982 Energy Projections [ref 1]. The DEn projections have a total of eight separate scenarios which include two separate assumptions on the level of world energy prices, three levels of GDP growth rate for the UK, and two cases of UK industrial structure. The Department scenarios were constructed as follows:

- a high case, with 2.5% per annum GDP growth rate, and both high and low world energy prices (DEn scenarios 'X' and 'A');
- a low case, with 0.5% per annum GDP growth rate, and both high and low world energy prices (DEn scenarios 'Z' and 'C');
- two sets of intermediate cases, with 1.5% per annum GP growth rate, each with high and low world energy prices, but different structures for industry (YU, BU, YL, BL).

89. In adopting output assumptions for the present study we were not able to explore all eight scenarios. We found that industry's own view of the future levels of output do not accommodate the full range of the scenarios in the 1982 Energy Projections. The X and A scenarios involve output levels which are higher than industry is generally prepared to consider, while the Z and C scenarios are lower. In consequence, we have constructed two scenarios, a high output case and a low output case, which are intended to explore a more limited range of output levels. In doing so, we have sought advice from various industry sources about the likely effect of changes in output and energy prices on specific energy consumption.

90. We have therefore based our two sample scenarios on the upper middle (YU, BU) and lower middle (YL, BL) scenarios from the 1982 Energy Projections. For each case, the 1982 Energy Projections provide four sets of output indices, which are shown in Figure 5, for iron and steel, building materials, chemicals and other industry. Possible structural changes in the proportions of output with each of these broad sectors have been discussed in the sector reports. For example, output of bricks and cement may not necessarily grow at the same rate. In the case of 'other industry', which includes food, textiles, engineering and the paper industry, different growth rates for each sector and subsector have been arrived at, subject to the constraint that the overall growth rates should agree with those in the 1982 Energy Projections.

91. Note that the output assumptions constructed in this way are intended to cover a range of expected futures, in order to explore the effects of somewhat different output levels on energy consumption and energy efficiency. In no sense are the output assumptions intended to be interpreted as forecasts for the individual subsectors; nor can either of the two scenarios

FIGURE 5: Industrial Output Indices from 1982 Energy Projections
(1980 = 100)

Year/Scenario	1990		2000	
Sector	YU, BU	YL, BL	YU, BU	YL, BL
Iron and Steel	146	121	168	110
Chemical	133	118	202	149
Building Materials	116	110	145	128
Other Manufacturing	114	111	138	128
Total Manufacturing	116	110	145	128

constructed be interpreted as the more likely outcome, nor can the range be considered to cover the full range of reasonably plausible futures.

ENERGY CONSERVATION POTENTIAL

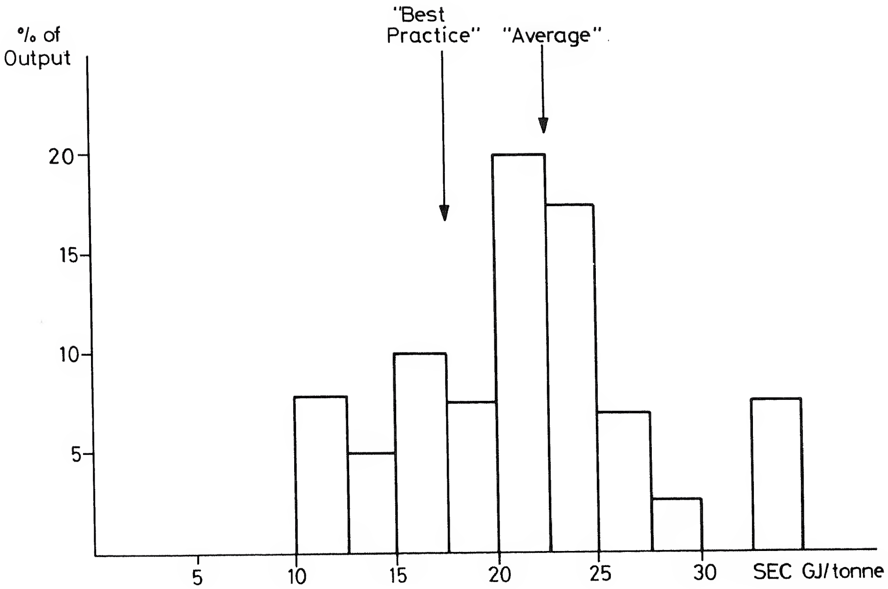
92. In Energy Paper 32 [ref 2], an estimate is made of the 'technical potential' for energy conservation for various industry sectors, disaggregated according to Minimum List Headings of the 1968 Standard Industrial Classification. Technical potential was defined as 'the long term savings which would be achieved through technological changes which can be identified now as technically feasible'. However, no attempt was made at that time to estimate the rate at which the potential could be realised (cf. paragraph 4).

93. The various reports in the Energy Audit and Industrial Energy Thrift Series identify the technical potential in specific subsectors in considerable detail. Some of these reports predate reference 2, and the information was therefore included in the energy paper; other reports have been prepared since. There is thus a considerable body of knowledge on technical potential for many of the subsectors of industry. A list of Energy Audit and IETS Reports is given in an annex to this report.

94. For many of the sectors where the Audit and IETS Reports are rather dated it has been necessary to go to industry sources, such as trade and research associations for an updated view of energy conservation potential. A list of organisations contacted is also given in the annex. The Energy Conservation Demonstration Projects (ECDP) Scheme, managed by ETSU on behalf of the Department of Energy, has also provided a useful source of information on technical potential, although it does not cover all forms of energy saving, and does not form a representative sample of industry.

95. To estimate how much of the technical potential is actually cost-effective now, or likely to become so, has proved to be a difficult task, since it requires information on the capital cost and energy savings of specific measures, which is often not available for reasons of commercial confidentiality. It has therefore been necessary in many instances to rely on the conclusions of the Audits and on industry sources concerning the cost-effectiveness of specific measures. In other instances, information is available from the ECDP scheme on specific projects. It is often difficult to generalise the economics of specific energy conservation projects, since cost and performance data tend to be unique to individual projects; although the ECDP scheme requires scope for replication through similar projects, each installation tends to have individual characteristics.

96. Much of the difficulty in determining how much of the technical potential for energy conservation is economic can be circumvented by identifying the current (1980) 'best practice' energy consumption in a given industry though this is not always straightforward in practice. 'Best practice' has been estimated in several ways in this study because neither the precise definition nor the quality of the available data have proved to be uniform over all the 44 subsectors examined. In principle, if the output of all the firms or establishments in each subsector are homogeneous and if the available evidence suggested that factors such as size and location make no significant difference to energy efficiency, then it would be correct to define 'best practice' as the lowest SEC observed in all the establishments



Note that the SEC for plant producing the lower 20th percentile of output is taken to be more representative of 'best practice' than the lowest SEC of the range.

FIGURE 6: Illustration of 'Average' and 'Best Practice' SECs for Different Plants Producing the Same Product

in the subsector. This implies that all establishments could, in principle, by management or investment achieve this level of energy efficiency.

97. In practice, there are two problems which make the lowest observed SEC a misleading measure of 'best practice'. First, there is great difficulty in achieving levels of disaggregation which ensure uniformity of output. Second, the data base for each of the subsectors is far from adequate. 'Best practice' was therefore established by considering the full range of SECs available, together with the size, location and product mixes of those establishments in the lower quartile. In most cases it was found that the establishments at the lower end of the SEC distribution were producing slightly different products or had particularly modern premises and hence their performance could not be readily achieved by other establishments in that subsector.

98. By 'best practice' we mean the specific energy consumption of the establishment or firm which appeared to have no characteristics of size, location or product mix which distinguished them from others in that subsector. For example, in the paper and board industry, a wide range of SECs was found, even for mills, within a single product group. Rather than take the lowest SEC of the range, it was generally found that the SEC for mills around the 20th percentile of the distribution could be judged to be representative of best practice. This is illustrated schematically in Figure 5. The difference between the lowest or 'best practice' SEC (SEC_{BP}) and the average SEC for the industry (SEC_{AV}) will represent at least a part of the potential for energy conservation; expressed in percentage terms, we define it as the 'best practice energy conservation potential', i.e.

$$\left(\frac{SEC_{AV} - SEC_{BP}}{SEC_{AV}}\right) \times 100$$

99. The best practice potential is, by presumption, economic, since it is based on production processes and operational procedures already in use within the industry. However, care must be taken to ensure that there are no special considerations which prevent the best practice from being more widely adopted. For example, the dry process for cement making cannot be applied to certain types of raw material. It does not therefore represent the best practice for all cement making.

100. Furthermore, the best practice in energy terms does not necessarily represent the most profitable practice, since other factors, such as capital and labour costs, must also be considered. For example, it cannot be assumed that it would be cost-effective for a firm operating at a higher SEC to replace plant prematurely in order to reduce the SEC. Thus, the best practice potential requires some period of time to become adopted through the industry.

101. **Hence, there are important elements of judgement involved in arriving at the best practice SEC (SEC_{BP}). It is not possible to estimate detailed uncertainty ranges but they are likely to be large, possibly 10-20%.**

102. There may be additional energy saving measures which could be taken by an industry, but which are not yet in use anywhere within the industry. This may be because the measure involves a new technology which has not yet

been sufficiently proved, or which needs further research and development. An example of this is the ALCOA process for aluminium smelting. Alternatively, the technology may be well developed, but would only be cost-effective if there were an increase in real energy prices. Certain applications of heat pumps fall within this category. In yet other cases, the adoption of new process technology could be stimulated by changes in relative fuel prices; for example, higher prices of oil and gas relative to coal and electricity could stimulate the introduction of technologies based on the latter fuels.

103. The energy saving which could be achieved by the introduction of new technology should this be or become cost-effective at some time in the future, is defined as the 'R&D Potential'. It can be expressed in percentage terms as the difference between the SEC of an industry operating the new technology (SEC_{RD}), and the SEC of an industry operating at existing best practice (SEC_{BP}):

$$\left(\frac{SEC_{BP} - SEC_{RD}}{SEC_{BP}}\right) \times 100$$

104. In order to estimate the specific energy consumption at some future date (SEC_F) it is necessary to estimate the extent to which the best practice potential and the R&D potential will be realised by that date. The best practice potential is, by definition, already technically available and economic. The rate at which it will be achieved will depend mainly on how quickly new production capacity is required, both to augment existing capacity and to replace obsolete or worn out capacity. This, in turn, will depend on:

- the future level of output, and
- the average lifetime of existing plant.

In each sector we have used judgement in consultation with the industries concerned to account for these major factors. Additionally, we have taken into account the likely circumstances surrounding the diffusion of innovation in the sector and the main features on which this complex process may depend.

105. The average lifetime of existing plant is itself a complex parameter. Although most items of production plant have a physical lifetime, this can generally be extended by refurbishment. The economic life of a plant can be shorter than the physical life because of rapid technical changes, an unexpected downturn in demand or competition from other suppliers. However, other things being equal, the average lifetime is determined by an economic trade-off between higher maintenance and running cost for the existing plant and the capital cost of a new plant. High energy costs should, in principle, favour the early replacement of existing plant with more energy efficient plant, because the saving in running costs would be larger.

106. In practice, however, improvements in energy efficiency appear to be related more to changes in output than to energy costs. Thus, an analysis of the change in energy efficiency by UK industry between 1968 and 1980, published by the Energy Research Group [ref 15], shows that energy efficiency

improved more rapidly in the five years before 1973, when energy costs were steady but output was growing rapidly, than in the following five years, when energy costs rose rapidly, but output stagnated. However, in 1980 a marked fall in output was accompanied by an improvement in energy efficiency, presumably because of the closure of older, less efficient plant.

107. A special case was the iron and steel industry, where the fall in output in 1980 was exacerbated by a prolonged strike, but was not accompanied by immediate plant closures. Thus, the specific energy consumption increased in 1980, partly because idle plant was kept hot during the strike, but fell sharply in 1981, when the less efficient plants were in fact closed, while output partially recovered, to increase the load factor of the remaining plant.

108. It is clear, therefore, that the introduction of new plant and the retirement of existing plant is a dominant factor in determining improvements in energy efficiency, but one which cannot be related in a simple analytical model to either energy cost or output.

SUMMARY OF METHODOLOGY

109. In this study we have adopted a disaggregated technological approach to describe the pattern of energy use in 1980 and identify technical opportunities for energy saving. In order to estimate the effect which these technical opportunities will have on future energy efficiency, we have to take account of their cost-effectiveness and factors influencing their rate of market penetration.

110. In Chapter 2, we discussed these concepts in general terms, and concluded that:

- cost-effectiveness can be determined by comparing the simple payback period of a measure with a required simple payback period;
- market penetration can be determined by a simple model based on an S-curve.

The application of these concepts depends in a highly uncertain way on:

- the nature of the energy saving technology;
- the nature of the industry sector involved;
- the level of economic activity assumed;
- the level of future fuel prices assumed.

111. In applying the basic concepts to individual sectors and technologies, a number of practical constraints were encountered, which should be noted.

112. For example, specific proposals for an energy conservation investment can in principle be subjected to investment appraisal in which the capital costs and expected savings can be estimated with a reasonable degree of certainty. However, it has generally proved difficult to obtain information on the economics of specific energy conservation measures, because of

commercial confidentiality. Even where such information is available it is not always appropriate to generalise from the results of particular projects, because circumstances can change significantly from one individual plant to another. Hence, in generalising about the cost-effectiveness of a measure across an industry, judgements must be applied based on a detailed knowledge of the industry.

113. Increases in energy prices will improve the cost-effectiveness of energy conservation measures, so that a measure which would be considered uneconomic at present energy prices might become economic in the future if energy prices rise. Alternative views of future energy prices can lead to different conclusions about the potential for energy conservation. Once again, however, generalisations across an industry are difficult.

114. To try to overcome these difficulties, we have attempted to determine only whether or not a particular energy saving measure was already cost-effective or likely to become so by the year 2000. Where a measure was already a feature of current best practice, then it was assumed that it was already cost-effective throughout the sector to which it is applicable, unless there were contrary indications. Where a measure was not yet a part of best practice, then the advice of informed industry sources was sought as to whether or not it would become so within the timescale of the study. We then applied a simple penetration model which did not seek to quantify all the various complexities involved in the diffusion process, but was based on the evidence available on observed patterns of penetration within the sector. Typically an S-type penetration curve with a 50% penetration time of 10-20 years was adopted.

115. In adopting this approach we have not been able to allow formally for the effect which rising fuel prices might have on accelerating the uptake of energy saving measures and this is one reason why this study cannot claim to provide alternative energy demand projections. However, we believe that it is preferable to rely on a simple penetration model than to attempt to devise a model which would seek to accommodate a range of influences which cannot in fact be readily quantified from the available information.

116. The sector reports in Volume II contain the detailed descriptions of the industry sectors and the energy saving technologies. In Chapter 5 of the present volume we give a brief description of each sector. Chapter 6 discusses general aspects of the various energy saving technologies. In Chapter 7, the results of our findings in Volume II are drawn together and discussed.

FIGURE 7: Industry Sectors Studied

Sector/Subsector	Corresponding SIC Heading	
	Class	Group/Activity
Metal Manufacturing	22	
Iron and Steel		221-223
Aluminium		2245
Copper		2246
Other non-ferrous		2247
Ceramic Materials	24	
Cement		242
Bricks		241
Refractories		2481
Potteries		2489
Glass		247
Misc. Building Materials		243-246
Chemicals	25	
Inorganic		2511
Organic		2512
Fertilisers		2513
Polymers		2514/5
Dyestuffs		2516
Paints		255
Pharmaceuticals		257
Detergents		258
Miscellaneous		256, 259
Paper	47	
Paper and Board Making		471
Conversion of Paper and Board		472
Printing and Publishing		475
Food, Drink and Tobacco	41, 42	
Dairy		413
Processed Foods		412, 414, 415
Bakery		416, 419
Sugar		420
Drink		424-428
Oils and Fats		411
Miscellaneous		418, 422, 423
Tobacco		429
Engineering	31-37	
Mechanical		320-329
Instruments		371-374
Electrical		330, 341-348
Vehicles		351-365
Metal Goods		311-316
Textiles	43,45, 26	
Wool		431
Cotton		432
Knitted Goods		436
Textile Finishing		437
Jute and Carpets		435, 438
Miscellaneous Textiles		433, 434, 439, 455
Leather		441, 442
Footwear and Clothing		451, 453
Man-made Fibres		260

5. DESCRIPTION OF THE SECTORS OF MANUFACTURING INDUSTRY STUDIED

117. In this chapter we describe the way in which we have disaggregated manufacturing industry. The energy intensity of the different sectors and subsectors is compared, using data from the 1979 Purchases Inquiry [ref 17]. A brief description of the main technical characteristics of each sector is given.

STRUCTURE OF DISAGGREGATION

118. We have divided manufacturing industry into seven sectors and 43 subsectors, as shown in Figure 7. The structure of the disaggregation used was determined largely according to well recognised definitions of separate industries for which there is a source of relevant data. Thus, industries like iron and steel, bricks, cement, etc. constitute natural entities and have organisations to represent them. In other cases, such as engineering and textiles, the boundaries and levels of sub-division are less obvious.

119. The main sectors are convenient groupings of subsectors which have obvious affinities. It is the subsectors which are the basic level at which the methodology is applied. In some subsectors, however, additional disaggregation is required to achieve the necessary degree of homogeneity in energy use among individual products or processes. For example, in non-ferrous metals, primary aluminium smelting is distinguished from secondary recovery of scrap, and the production of semi-fabricated aluminium products.

120. As far as possible, the disaggregation has been related to the 1980 Standard Industrial Classification (SIC) [ref 16]. However, difficulties arise because much of the available data has been collected and assembled according to the 1968 Standard Industrial Classification. Care must be taken when comparing data, to ensure that they correspond exactly.

121. The old 1968 SIC divided industry into 27 orders, each of which was sub-divided into a number of 'minimum list headings' denoted by a three-digit number. The 1980 SIC, which was introduced principally in order to harmonise the UK classification system with that of the European Community, is based on a decimal notation. The full range of industrial activity, from agriculture to banking, is divided into 10 divisions, each denoted by a single digit from 0 to 9. The divisions are sub-divided into classes (each denoted by the addition of a second digit), the classes into groups (three digits) and the groups into activity headings (four digits).

122. We are only concerned with manufacturing industry, which corresponds to divisions 2 to 4 of the SIC. The energy producing and water supply industries (division 1) and construction (division 5) are not included in this study. Figure 7 shows the various sectors and subsectors into which manufacturing industry has been disaggregated, and the corresponding SIC classes and groups/activities. The subsectors are described, where possible, by single words. For example, 'polymers' covers synthetic resins and plastics and synthetic rubber. For each subsector, the extent of the coverage is indicated by the SIC group or activity number, as appropriate. Note that the term 'ceramic material' is used in its technical meaning of 'non-metallic inorganic material'.

123. A small deviation from the 1980 SIC should be noted. In this study, casting of metal is dealt with as part of metal manufacturing rather than engineering. This is because:

(a) it is an energy intensive activity which bears close resemblance in energy use terms to the other activities in metal manufacturing, which involve the melting of metals, and

(b) the data relating to it is included in audits of the respective metal industries.

However, cutting, stamping and other means of converting semi-fabricated metal products into finished goods are properly treated as the metal goods subsector of engineering.

124. The extraction of ores (class 21) and minerals (class 23) are very small energy using activities, and are not included in this study. Apart from these two minor omissions, however, all of divisions 2-4 of the SIC have been covered in this study.

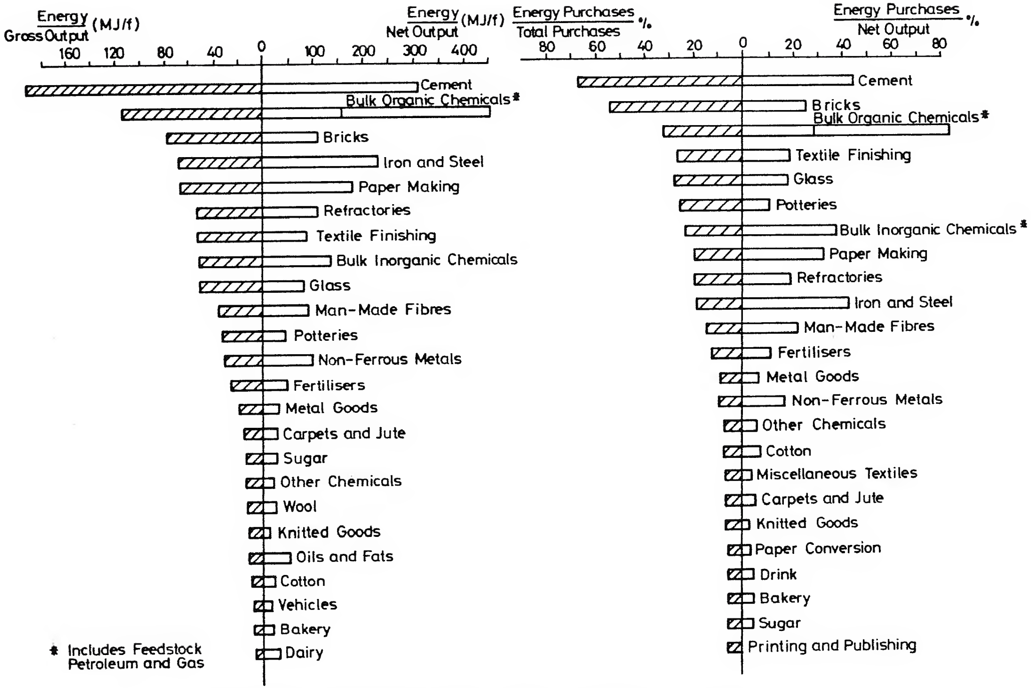
ENERGY INTENSITY COMPARISONS OF SECTORS

125. In Chapter 2, it was noted that the relative importance of energy to an industry could be measured in several ways using energy intensity ratios. Table 1 in Annex 4 shows 1979 data on energy consumption in PJ and energy purchases in £M, together with total purchases, gross output and net output for the various subsectors. These data have been taken from the 1979 Purchases Inquiry carried out by the Business Statistics Office [ref 17]. Similar data for 1980, the base year of the present study, are not available in a form which allows comparison between subsectors. It is, nevertheless, useful to compare the different energy intensity ratios for the subsectors. Figure 8 shows the comparisons graphically.

126. The most energy intensive subsector in terms of energy purchases/£ gross output is cement, with bulk organic chemicals ranked second. However, the ranking is reversed when energy purchases/£ net output is considered. This reflects the fact that the non-energy raw materials for cement production (limestone and clay) are cheap, whereas for bulk organic chemicals they are more expensive. In the cement industry energy purchases account for 67% of total purchases. In bulk organic chemicals, energy purchase (including feedstock from petroleum) accounts for only 32% of total purchases; 50% of purchases are precursor organic chemicals, traded within the subsector.

127. Similarly, the brick industry is more energy intensive than the iron and steel industry on a gross output basis, but less energy intensive on a net output basis. The raw materials for brick making are cheap, hence energy accounts for 54% of total purchases. In the iron and steel industry, however, energy accounts for only 18% of total purchases, which include semi-fabrication steel products (ingots, etc.) traded within the sector.

128. There are nearly two orders of magnitude difference in energy intensity across the range of subsectors studied, from 467 MJ/£ net output for bulk organic chemicals to 5.4 MJ/£ net output for printing and publishing. Subsectors which are energy intensive can be distinguished from subsectors



* Includes Feedstock
Petroleum and Gas

Fig.8 Comparison of Energy Intensity Ratios for Subsectors of Industry

which are not energy intensive, with a dividing line set arbitrarily at 50 MJ/£ net output. On this basis, the energy intensive industries account for 74% of energy consumption, but only 24% of net output. There is a five-fold difference in the average energy intensity between the intensive and the non-intensive subsectors.

TECHNICAL DESCRIPTION OF THE SECTORS

129. In the following paragraphs, a brief description is given of the main characteristics of each of the sectors studied.

Metal Manufacturing

130. Recent years have seen a market contraction and structural reorganisation in the metal manufacturing sector. Nevertheless, it is a large and highly intensive energy user, accounting for 21% of total energy use in manufacturing industry in 1980. The iron and steel industry alone accounts for 80% of energy use in the sector. The closure of older, less efficient plant has reduced the SEC for steelmaking by 10% between 1978 and 1981. Similar improvements have been observed for the non-ferrous metal industries.

131. Energy is used in metal manufacturing for:

- smelting of metal ores;
- refining of scrap metal;
- processing of metal ingots into semi-fabricated form (strip, plate, tube, etc).

The total energy required for a given output of semi-fabricated product depends largely on the relative proportion of virgin metal and scrap used, since refining scrap requires very much less energy than smelting ores. An increase in scrap utilisation reduces energy consumption. The possibility of increased imports of metal ingots is a source of considerable uncertainty in the projections of energy use in this sector, especially in the case of aluminium.

132. Virtually all of the energy used in this sector is for high temperature processing. Integrated iron and steel-making based on the smelting of iron ores uses mainly coke, and accounts for about two-thirds of steel production. The remaining one-third is produced from scrap in electric arc furnaces. Aluminium smelting is an electrolytic process which consumes large amounts of electricity, much of it privately generated either by hydroelectric power or from purchased coal. Semi-fabrication of metals generally involves working the metals at high temperature; the metal is heated largely by fuel oil or natural gas, although electric induction heating is increasing in the non-ferrous subsectors.

133. Because 1980 is such an anomalous year for the iron and steel industry, due to a prolonged strike, the analysis of the industry in the sector report is based on 1981 data. Specific energy consumption for the industry is based on the output of crude steel rather than finished steel. Energy consumption

in coke-making is excluded from the SEC because coke-making is regarded as part of the energy supply industry rather than the iron and steel industry.

Ceramic Materials

134. Ceramic materials are non-metallic inorganic materials, such as bricks, cement and glass used in the construction industry, refractory materials used in the process industries and pottery and glass for domestic and general use. The common characteristic of these industries is that they involve high temperature firing of relatively cheap raw materials - principally clay, limestone and sand.

135. In 1980, the sector used 214 PJ of energy (13% of the total for manufacturing industry). The largest subsectors in energy consumption terms are cement (79 PJ), miscellaneous building materials (49.1 PJ) and glass (42.5 PJ), which together account for 80% of the energy use by the ceramic materials sector. The most energy intensive subsectors, however, are the cement and brick industry (cf. Table 2 in Annex 4).

136. More than half of the cement produced in the UK is made by the so-called 'wet' process, which requires about 50% more energy than the 'dry' process, and 30% more than the 'semi-wet' process. Although the dry process is not suitable for some UK raw materials, it is expected that competitive pressures will cause the wet process to be replaced by dry or semi-wet processes by the end of the century.

137. In the brick industry there are two broad types of product and process which have radically different energy requirements. 'Fletton' bricks are made from a clay which naturally contains a high content of carbonaceous material, which provides much of the energy required for firing. Consequently, the requirement of conventional fuels is only ~ 30% of that required for non-fletton facing bricks. Fletton bricks, which are made exclusively by a single company, account for approximately 50% of production in 1980, but only 20% of energy consumption. Non-fletton facing and engineering bricks are, however, premium quality products which, in spite of their higher energy requirement, are expected to increase their market share.

138. The glass industry is mainly concerned with the manufacture of glass bottles and window glass. The pottery industry produces china, earthenware, ceramic tiles, etc. by the firing of clay at temperatures of 1100-1250°C. Refractory materials are materials which can withstand high temperatures and are used to line furnaces and kilns. They are made by firing suitable raw materials (e.g. magnesium carbonate, alumina and silica) at temperatures up to 2000°C. In all of these industries the main fuels are oil, LPG and gas.

139. The miscellaneous building materials subsector is concerned with a diverse range of intermediate products, such as concrete blocks, plaster board, abrasive materials and bitumen-coated stone for road-making. Energy is used, mainly in the form of oil and gas, for drying, firing and melting of bitumen.

Chemicals

140. The chemicals sector used a total of 324 PJ of energy in 1980 (excluding 291 PJ of petroleum and natural gas used as feedstock for bulk inorganic and organic chemicals). The sector as a whole accounts for 20% of the total energy use by manufacturing industry. The main subsectors are bulk inorganic and organic chemicals, which account for 58% of energy use in the chemicals sector.

141. Bulk inorganic and organic chemicals are intermediate products which are mostly used within other subsectors of the chemicals sector. The main inorganic chemicals are nitric acid, sulphuric acid, chlorine and caustic soda (sodium hydroxide). Organic chemicals, such as ethylene, benzene, alcohols and formaldehyde, are made from petroleum feedstock and used for the production of plastics, pharmaceuticals, dyestuffs, detergents, etc.

142. Energy use in the chemicals sectors is mostly in process plant, much of it using steam for distillation and evaporation, but with some direct firing of kilns and furnaces. Electrical energy is used for electrolysis in the chlor-alkali industry.

143. There is considerable private cogeneration of steam and electricity in CHP plant; the chemicals sector accounted for 37% of privately generated electricity in industry in 1981.

144. Process heat is often used at a variety of different temperatures in different processes within a single plant or complex. Some parts of a process need cooling, either because of temperature drop from a preceding process or because the process itself is exothermic (e.g. sulphuric acid manufacture). Chemical plant is therefore designed to optimise heat recovery, with energy cascaded from the higher temperature processes to the lower temperature processes.

Paper and Printing

145. The paper and printing sectors consists of three very disparate industries:

- paper making (including conversion of pulp)
- conversion of paper and board
- printing and publishing.

The former is an energy intensive industry, while the latter two are not.

146. Paper and board-making used 93 PJ of energy in 1980, mostly as process heat for drying (60 PJ). The main fuel for boiler-firing is oil (38%) which largely displaced coal in the 1960s, but has in turn been somewhat displaced by gas more recently. Coal retains a 26% share of the total energy use, but mainly in the older plant; gas, with a 24% share, tends to be used in the newest plant. Electricity accounts for 11% of energy use; it is used extensively for motive power, especially in the pulping and refining stages of paper making.

147. Conversion of paper and board includes the manufacture of wallpaper, cartons, etc. from paper and board. 1980 energy consumption is estimated to be 23 PJ. Printing and publishing used 19 PJ in 1980, mainly for space heating (74%), using oil (32%) and gas (44%).

Food, Drink and Tobacco

148. The food, drink and tobacco sector used 176 PJ in 1980, or 11% of the total energy used in manufacturing industry. Energy use is spread across the subsectors fairly uniformly, with the drink (brewing and distilling), sugar and dairy industries being the largest energy users. The tobacco subsector is a very small user of energy, with the lowest energy intensity of all the subsectors in this study.

149. Most of the energy used in the food, drink and tobacco sector is low temperature process heat delivered as steam for cooking, evaporation and sterilisation and hot water for washing, etc. The oil and fats and sugar industries involve moderately high temperature processes (200-300°C) which are quite energy intensive. About 29% of the total energy use across the sector is for space heating. Electricity is used extensively for refrigeration as well as motive power and lighting.

150. Oil and gas are the main fuels used in the food, drink and tobacco sectors. Coal accounts for only 14% of total energy use across the sector, but in the sugar industry it accounts for 35% of energy use.

Engineering

151. The engineering sector accounted for 304 PJ, or 19% of total energy use in manufacturing industry in 1980. The sector covers a very wide range of products, such as cutlery, textile machinery, office equipment, cars, ships, aircraft and clocks; it accounts for ca. 46% of the total output of industry in net monetary terms, and thus has a low energy intensity.

152. The pattern of energy use across the sector is fairly uniform, with around 65% of all energy used for space heating. Electricity is used extensively for motive power for metal cutting machines and for compressed air and some metal heating. Some high temperature process heat is required for melting metal, galvanising, annealing, etc., while low temperature process heat is required for drying and curing plant, etc.

153. Oil and gas together account for 69% of the energy use; 9.6% is supplied by coal and 21.7% by electricity.

Textiles, Leather and Clothing

154. Like engineering, the textile sector covers a wide range of products and processes. In this case, however, there is a more significant variation in energy use among the various subsectors.

155. The sector as a whole used 120 PJ in 1980, or 7.5% of total energy use in manufacturing industry. Textile finishing and the production of man-made fibres together account for 46% of the sector total, and involve relatively energy intensive processes.

156. The main use of energy is process heat for washing and drying, supplied as steam and hot water from boilers fired mainly by oil, which accounted for almost 50% of energy use in 1980. About 32% of energy was used for space heating. Electricity (18% of total energy) is used extensively for operating textile machinery, as well as for lighting.

Other Trades

157. Note that this study excludes those industries grouped under 'other trades' in the 'Digest' [ref 18]. This group includes the construction, water supply and mineral extraction industries which do not fall within Divisions 2-4 of the SIC and are not part of manufacturing industry as we have defined it. However, 'other trades' also includes:

- timber and furniture industries (SIC 461-467)
- processing of rubber and plastic (SIC 481-483)
- other manufacturing industries (SIC 491-495).

These manufacturing industries together consumed 148 PJ in 1979 [ref 17], but have not been included in this study because of insufficient data.

6. TECHNOLOGIES FOR ENERGY SAVING

158. The wide diversity in the uses of energy in different manufacturing processes is reflected in the corresponding technologies available for improving the efficiency of its use. The sector reports in Volume II of this study describe in detail the scope for application of these technologies. Here, we examine some of the more important technologies in general terms, and identify common features in their application.

MONITORING AND TARGETTING

159. The most generally applicable approach to energy saving is monitoring and targetting of energy saving. This approach is based on the concept that better information on where and how energy is used in a process is a prerequisite for any energy saving programme. A recurrent conclusion of many energy audit and thrift reports is that even in energy intensive industries managers have poor information about their energy use, often limited to overall financial expenditure by a site on a quarterly basis.

160. Monitoring and targetting is a systematic approach to energy management in which detailed measurements are made of energy consumption and reported regularly to higher management. It provides managers with detailed information which allows targets to be set and performance monitored, and leads to energy savings in two ways:

- direct savings result from an increased awareness of energy consumption, without any further investment in plant or equipment,

- opportunities for further energy-saving are identified, which do require investment.

The direct savings of energy can be significant. For example, in a pilot programme carried out in four paper mills by the British Paper and Board Industry Federation, savings of up to 13% of energy consumption were observed in the first year of operation [ref 19]. This programme is currently being extended to other mills in the paper industry, and direct savings of at least 5% of energy consumption are expected across the industry.

161. The Department of Energy is actively promoting the monitoring and targetting approach throughout industry. However, one of the main obstacles to the wider adoption of the approach is the initial cost of establishing an appropriate system both in management time for planning the system and in hardware for improved measurement of energy consumption.

WASTE HEAT RECOVERY

162. It is a fundamental principle of thermodynamics that virtually all of the energy put into a process is discharged as waste heat. The only exception is energy stored in the chemical transformation of materials (e.g. smelting of ores into metals). However, the quality of the energy may be degraded by the process, either by lowering its temperature or by the contamination of hot gas or liquid effluent with impurities.

163. Low temperature waste heat is widely discharged in the aqueous effluent from washing processes especially in the food and textile industries, and

as moist air in drying processes, especially in the paper industry. Recovery of the waste heat requires large areas of heat exchangers to transfer the heat to a suitable input stream, e.g. preheating the washing water or the air input to driers.

164. The opportunities for reusing low temperature waste heat may be limited, especially where it is available in large quantities. Suitable heat loads are typically for space heating, preheating boiler feedwater and hot water for washing processes.

165. In many processes, the waste heat is discharged at a temperature which is too low to be useful, e.g. 30-40°C. It can be made more useful, however, by using a heat pump to raise its temperature to, say, 80°C. There are a number of heat pump demonstration projects of this type in operation, notably in the food sector.

166. In some circumstances it is economically favourable to use the shaft power from an engine to drive both a heat pump and some other equipment, such as an electricity generator or air compressor. Additional heat recovery from the engine itself is incorporated into the system.

167. Even if a suitable use can be found for the recovered heat, the adoption of low temperature waste heat recovery depends on the economics involved. Each opportunity must be considered on its merits. The capital cost of the heat exchangers and ancillary equipment, and the financial value of the heat recovered, determine the payback period for a particular opportunity, which is then compared with a required payback determined by a firm's investment priorities (cf. paragraph 45). Many waste heat recovery opportunities have marginal economics, with paybacks in the range 3-5 years. It follows that the potential for waste heat recovery would be increased by:

- reducing capital costs of equipment;
- increasing heat transfer efficiency;
- increasing fuel costs;
- relaxing economic payback criteria.

168. The problems with recovering waste heat from high temperature processes are somewhat different. There is often a large amount of heat at temperatures of 1,000-1,400°C in the exhaust gases from furnaces and kilns in the metal and ceramic sectors of industry. Use of heat recovery techniques such as ceramic heat exchangers and regenerators is already known, for example in the iron and steel and glass industries, to preheat combustion air. Indeed, their use declined in the period between 1950 and 1973 due to the advent of cheap oil in place of low-calorific value coal gas (which often required preheated air to produce a high flame temperature).

169. High temperature heat recovery requires materials capable of withstanding the temperatures involved. In many cases the gases are highly contaminated with acids and particulates, which cause corrosion, abrasion and fouling of the heat exchangers.

170. A further limitation on waste heat recovery is sometimes a lack of opportunity for using the waste heat within the process or plant. This is particularly true in the cement and brick industries. In principle, the heat could be used to generate electricity via steam turbines for export to the grid. The economics of this depend on the price obtained for the electricity. The Energy Act 1983 will ensure that, in future, this price will be properly related to the electricity supply industry's costs of alternative supply, so that the private generator is not at an unfair disadvantage.

171. An important new development in high temperature waste heat recovery is the regenerative burner system which has been developed recently by British Gas. This system is capable of recovering heat from both clean and contaminated gas streams at temperatures up to 1,400°C. It is claimed to give fuel savings of 55-60% over conventional burners and 20-30% over recuperative burners operating under similar conditions, and is applicable to a wide range of ovens, furnaces and kilns from which large quantities of waste heat are presently vented to the atmosphere.

PROCESS INTEGRATION

172. 'Process integration' is the term used to describe a chemical engineering technique recently pioneered by Linhoff and ICI for the design of energy efficiency plants. Applied to new plants, energy savings of up to 25% compared with conventional methods have been achieved [ref 20].

173. In the chemical industry, the cascaded nature of energy use means that energy flows are complex, with many stages of heat recovery and reuse, especially in the range 100-300°C. The design of plants requires a lot of effort and ingenuity to determine the optimum arrangement of heat exchangers, and an economic trade-off must be made between the capital cost of heat exchangers and energy consumption.

174. The key feature of the Linhoff-ICI approach is that it first establishes a target for the minimum energy required to drive the process. A heat exchange network is then designed to achieve the minimum energy target, following a systematic procedure. The minimum energy design is then optimised for cost-effectiveness in an iterative procedure, by modifying the design to reduce capital cost while accepting the penalty of increased energy requirement.

175. The significance of the procedure is that it sets out to establish the minimum energy configuration first. Conventional design approaches tend to start with the minimum capital cost configuration. By focusing attention on energy requirements, energy efficiency design solutions are obtained which would otherwise be missed.

176. The method has also been applied successfully to the redesign of existing plants with the aim of reducing their energy requirements. Typically, savings on bulk organic or petrochemical plants of 25-30% have been achieved, with paybacks in range 6-12 months.

177. There may be a number of opportunities for applying the process integration technique to complex processs outside the chemical industry, e.g. paper making, textile finishing and food processing. The usual approach to

energy management involves the identification of energy saving opportunities, which are ranked according to payback criteria. This approach means that the best opportunities are selected, but they might not represent the best use of capital and effort. The process integration approach ensures that an optimum strategy for allocating cost-saving resources is devised.

CONTINUOUS PROCESSING

178. Continuous processing techniques, such as continuous casting of metals, and tunnel kilns in the brick industry, can lead to energy savings compared with batch processing techniques. Energy requirements are lower because:

- cooling and reheating of materials between intermediate process stages is avoided;
- the throughput is generally faster, so that materials are not held at the process temperature for as long a time;
- the processing equipment is smaller, has less thermal mass and is not cooled and reheated between batches;
- recovery of heat from the output material can be more easily recycled to the input material.

179. However, energy saving is not the only advantage of continuous processes. Other advantages may be:

- higher labour productivity;
- higher yield;
- better product quality.

Hence the cost-effectiveness of a continuous processing technology does not necessarily depend on the energy savings alone.

180. In the iron and steel industry, continuous casting of liquid steel avoids many losses in the traditional casting route, including 'soaking pits' in which steel ingots have to be kept at high temperature for many hours, cropping of the ends of the ingots and reheating for primary rolling. The resulting energy saving is about 1.8 GJ/tonne of crude steel, or approximately 8% of the total energy requirement for steel-making. Furthermore, a more consistent quality of steel is obtained, which is more suitable for some applications than ingot-cast steel. Approximately 35% of steel production is cast continuously at present; the proportion is expected to rise to about 70% by 2000.

181. Tunnel kilns are now used for 70% of production of bricks from non-carbonaceous clays. However, the rest of brick production uses the quasi-continuous annular chamber kiln method in which recovered heat is transferred between batches of bricks at different stages of the production process. There is therefore little if any energy saving to be made by extending the use of tunnel kilns.

182. There is scope for the further application of continuous processing techniques in a number of processes in the non-ferrous metals industries, and parts of the pottery, food, textile and engineering sectors. Paper-making is, of course, already a continuous process, although the full potential for heat recovery inherent in its continuous nature has yet to be realised.

183. Batch processing techniques will continue to be favoured for short production runs of low volume products, such as speciality chemicals and alloy steels, and for products where the required quality of product can only be obtained by a batch production method, e.g. whisky distilling.

STEAM SYSTEMS

184. A large proportion of the heat used in manufacturing processes is used as steam raised in a central boiler house and distributed around the site in reticulated steam pipes. The steam is effectively a heat carrier; the latent heat of evaporation is given up when it condenses at the heat emitting surface. The condensate contains a considerable amount of residual heat and should be collected and returned to the boiler for re-use.

185. Inefficiencies in steam-systems are frequently cited in energy audit and thrift studies as a significant opportunity for energy saving. In many cases, the generation of steam at the boiler house is efficiently controlled, but poor maintenance of the distribution system, inadequate insulation of pipework and careless use of the steam by process operators results in energy losses.

186. Few firms know what their steam costs are or how the steam is used. Metering of steam as it leaves the boiler house and again as it enters into each major process or department within a works provides the means by which losses and abuses can be controlled.

187. Efficient use of process steam requires good maintenance and operation of the steam distribution system. For example, trapped air and condensate films in heating coils reduce heat transfer to the process, and should be avoided. Steam traps, which separate the condensate from the steam, must be correctly positioned to avoid waterlogging. The accumulation of dirt in steam traps causes leakage of steam.

188. When condensate under pressure is released to atmosphere, 'flash' steam is generated which represents a heat loss unless steps are taken to collect and use it. Many examples of flash steam recovery are available, but the technique could be more widely adopted.

189. Even for well-maintained steam systems thermal efficiencies are only 50-60% at best; poorly-maintained systems can be much worse, due to distribution and end-use losses.

190. Alternative ways of providing process heat directly at the point of use can increase system efficiency. For example, British Gas have developed a gas-fired small-bore immersion tube for heating liquids in tanks and vats, with a thermal efficiency of about 80% [ref 21]. The payback time for installing a gas-fired immersion tube in place of a steam-heated immersion tube is about 1-2 years.

PROCESS CHANGE

191. The energy required to produce a given material or product can be greatly reduced by the adoption of new production processes. Energy intensive processes fall into two main categories:

- processes which require high temperatures to effect a chemical transformation, e.g. manufacture of metals;
- processes which require removal of water, e.g. paper making, textile finishing.

192. There are a number of examples of new processes which reduce the energy required for high temperature processes. For example in the iron castings industry, a novel proprietary permanent mould system is the subject of an EEDPS demonstration project [ref 22]. Energy is saved because the yield of cast metal is greatly enhanced, which reduces melting requirements, and several additional process steps are avoided. Another example is powder metallurgy. This is a novel approach to semi-fabrication of metals which is still under development. Instead of pouring molten metal into a mould, the required shape is formed from metal powder which can then be sintered at a lower temperature than the melting point of the metal.

193. The energy required to evaporate water from a product can be reduced either by reducing the amount of water used in the first place, or by use of a more efficient method of removal. An example of the former approach is the dry process for cement manufacture, which is widely used in Europe, but accounts for only ca. 30% of UK production. The wet cement process is still dominant in the UK, partly because of the nature of much of the available raw materials. However, drier processes which can accept these raw materials are being introduced in the UK.

194. Dry-forming of paper also avoids the large amount of energy required to evaporate water from wet pulp. At present, the technique has found only limited application for soft tissue paper, but future development may extend its range of applicability.

195. More efficient methods of drying include multiple effect evaporators, in which the latent heat of the water vapour is recovered; mechanical dewatering, which squeezes the water out; vacuum dewatering, which sucks it out; and radio-frequency drying, in which electrical energy is transferred directly to the water with high efficiency. Many of these techniques are starting to be applied in the paper, food and textile industries.

196. Other energy intensive processes which are widely used in different industries are crushing and grinding of solids, and distillation of non-aqueous liquids. The former accounts for a considerable proportion of electricity use in the cement, brick and paper industries, while the latter is used extensively in the chemical industry. Although much can be done to make these processes more efficient, there is at present no radically novel way in which they can be avoided.

PRODUCT MODIFICATION

197. In certain circumstances, a product or material may be overspecified in terms of strength or purity; it may then be possible to reduce the energy required to produce the product by modifying its specification. However, this may involve a change in statutory standards or customer acceptance, which may in turn require extensive demonstration that the proposed modification is not deleterious.

198. For example, the energy required to fire bricks with high levels of perforations (i.e. holes passing through the bricks) can be 20-30% less than for solid bricks. At present UK building regulations allow bricks with up to 25% perforation for structural brickwork, but only 10% of output is currently perforated, typically with only 10-12% perforation. There is considerable scope to increase perforations within the existing regulations. The regulations themselves are, however, rather arbitrary; in continental Europe some buildings have bricks with more than 40% perforation.

199. The production of blended cements using pulverised fuel ash (PFA) from power stations and granulated slag from blast furnaces significantly reduces energy consumption compared with standard Portland cement. Blended cements are used more extensively in Europe than in the UK, but UK manufacturers are now considering increased use of blending materials. A draft British Standard for PFA cement has been prepared; standards for blast furnace cement already exist.

200. The amounts of steel and other energy intensive materials used in manufactured goods can often be reduced, either by substituting plastics or other materials, or by adopting more critical designs to achieve the required strength with less material. For example, car bodies increasingly use glass-reinforced plastic or other plastic material for non-loadbearing panels, while computer-aided design of the main body-shell allows the use of thinner steel sheet. Another example is the recent introduction of a lightweight milk bottle, which reduces the amount of glass required. There is also a trend towards substituting plastic containers for glass bottles.

201. Many of these trends towards product modification do not affect specific energy consumption per unit of physical output for the materials or products concerned. Rather, they influence the total output of steel, glass, etc. Although this influence is ultimately reflected in the total energy consumption of manufacturing industry, it is not possible to separate its impact on improved energy efficiency from other structural changes in output which are not related to energy efficiency.

MATERIAL RECLAMATION AND RECYCLING

202. Recycling scrap materials, such as metals, glass and paper, saves the energy required to produce virgin material. In the most extreme example, the energy required to recover secondary aluminium from scrap is one twentieth of the energy required to produce primary aluminium from bauxite. Consequently, scrap aluminium is a valuable resource, which is reflected in the high prices paid for it (around £400/tonne). Nevertheless, the proportion of UK aluminium consumption which is derived from scrap is only about 30%.

203. Other non-ferrous metals, such as copper and lead, tend to be used in a form which is easily identifiable and collectable, such as pipework, batteries, etc., and are more efficiently recycled. By contrast, aluminium is used extensively as a packaging material which is ultimately disposed of through domestic refuse.

204. Much of the content of domestic and industrial refuse is in principle recyclable, provided that the various materials can be reclaimed in a usable form. One approach to reclamation is to encourage segregation of the valuable energy-intensive material at the point of initial disposal, e.g. by individual consumer.

205. Alternatively, municipal refuse can be sorted in centralised plants by the disposal authorities. Large, automated plants for carrying out this procedure are under development in a number of countries, including the UK. Electromagnets separate ferrous metals, while non-ferrous metals, glass and plastics are separated by mechanical means. The remaining material is largely composed of paper and other organic materials (e.g. food wastes) which may be converted into a pelletised fuel. In the future, it may be possible to segregate non-ferrous metals by using tunable induction magnets.

206. The limitation on reclamation of waste materials is largely an economic one, determined by the costs involved in collection, sorting and cleaning the recycled material. For example, more energy can be saved by recycling glass bottles whole rather than as broken glass. For some applications, such as milk distribution, the infrastructure for collecting and recycling the bottles exists. However, for most purposes, it is more expensive to recycle bottles than to use one-trip bottles, from which some energy can nevertheless be saved by recycling the glass content of bottles through the glass-making process.

207. It may be more economic to recover the energy content of refuse by burning it without any attempt at segregating the higher value materials from it. For example, unsegregated refuse can be burnt in a cement kiln relatively easily; the ash becomes incorporated in the product without any adverse effect on quality. Some of the calorific value of refuse which is disposed in landfill sites can be reclaimed as a combustible gas (mainly methane) which is generated by biological action.

208. From the foregoing discussion, it can be seen that there is considerable technical scope for improving the efficiency of energy use in manufacturing industry. The extent to which these energy saving technologies are deployed in the future depends on many factors, including those involving cost-effectiveness and diffusion rate which have been discussed previously. The sector reports analyse specific technologies in detail and estimate their future uptake.

209. Their uptake also depends on the response of individual people, whether as managers, process operators, designers or consumers to the opportunities for energy saving. There is thus a social aspect to the more rational use of energy. However, no attempt has been made to analyse this aspect systematically, for example, by investigating how individual behaviour might be influenced by marketing techniques.

7. FINDINGS OF THE STUDY

210. In this chapter we present the numerical findings of our study. The detailed analysis at the sector and subsector level is presented in the individual sector reports in Volume II. Here we are concerned with building up an overall view of the changing pattern of energy use in industry, based on a summation of the detailed findings.

211. In Chapter 5 we have already examined the structure of disaggregation used in the study, while Chapter 6 discussed the generic technologies for improving energy efficiency. Here we examine:

- the pattern of energy use in 1980, broken down by sector and subsector, by fuel type and by final use;
- the improvements in energy efficiency which we consider are likely to happen up to the year 2000 in each sector and subsector;
- the effect which these improvements in energy efficiency would have on total energy consumption in illustrative scenarios of output described previously (paragraphs 75-79).

212. The detailed data for each subsector are given in a set of tables which have been grouped together in Annex 4. The resultant overall pattern which emerges from the summation of the tables is shown in Figure 9 which is displayed alongside the relevant text. Thus the reader is invited to follow the broader findings from the study by inspecting the figure, and turn to the tables for the more detailed findings.

213. As we have previously described in Chapter 2, we have chosen to adopt specific energy consumption (SEC) as a measure of the efficiency of energy use. For each subsector studied, the sector reports provide a value for the SEC in 1980, and an estimated value of the SEC in 1990 and 2000 for the two scenarios of output. These SECs are shown in Tables 2 and 3 in Annex 4, together with the corresponding values of output. Where possible, output is measured in terms of kilotonnes of product, with the SEC given in GJ/tonne. For textiles and engineering and parts of other sectors, however, output can only be measured in monetary terms (£M gross output), with the SEC expressed correspondingly as GJ/£k gross output.

214. The SEC for a subsector is an average value for the subsector as a whole. In many subsectors, there are a number of separate products for which different SECs have been specified in the sector report. For example, the dairy subsector considers liquid milk, cheese and butter separately, with different growth trends in the output of each product specified in the assumptions. Hence, the change in the average SEC for the dairy subsector from one year to another includes an element of structural change in the output of the subsector as well as an improvement in energy efficiency.

215. Multiplying together SECs and sample output assumptions provides us with an illustrative set of energy consumption figures. To break these figures down by fuel type and by final use involves very large uncertainties but the sector reports include an analysis of the pattern of energy use in 1980, together with tentative estimates of how this pattern might realistically change up to the year 2000.

THE PATTERN OF ENERGY USE IN 1980

216. Figure 9 summarises our findings for the pattern of energy use in 1980 in heat supplied terms, broken down by (a) sector, (b) fuel and (c) final use. The corresponding detailed data at the subsectoral level is given in Tables 4 and 5 in Annex 4.

217. The main fuel types are:

- solid fuel (coal, coke, etc.)
- petroleum (including LPG)
- natural gas
- electricity
- other gases (coke oven gas, landfill gas, etc.)

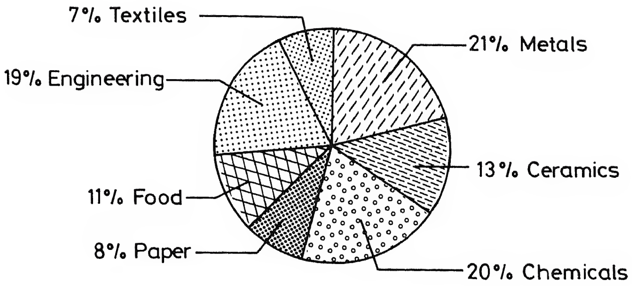
The final use categories are:

- electrochemical energy and process heat > 300°C
- process heat < 300°C
- space heating
- motive power and lighting.

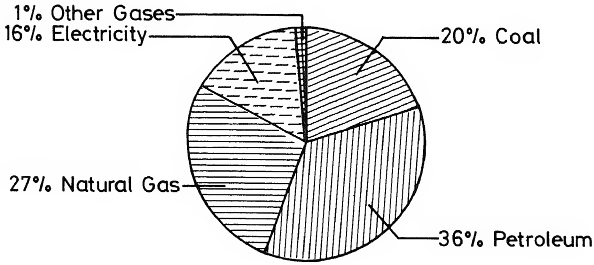
218. The data shown in Figure 9 and Tables 4 and 5 have been derived from a variety of different sources, such as industry federations or trade associations and research associations; in instances where there was no suitable industry source, the BSO purchases inquiry [ref 17] has been used. The data sources used in this study therefore originate with the energy users rather than the energy suppliers, who provide the data in the 'Digest of UK Energy Statistics' [ref 18].

219. Comparison of the sector totals from Table 4 with the corresponding 'Digest' data [ref 18] provides a useful check on the overall coverage of industrial energy use provided by the disaggregation in the present study, and on the accuracy of the data obtained. Figure 10 shows this comparison for total energy use, broken down by the main industrial groups used in the 'Digest', which correspond broadly to the sectors used in this study. Similarly, Figure 11 compares the breakdown by fuel type. (The numerical values for these figures are given in Tables 6 and 7 in Annex 4.) It can be seen that the estimates for total energy use agree very closely, but there are some variations both at the sectoral level and in the fuel mix. This suggests either that the disaggregated data are subject to some degree of random error which tends to cancel out in the aggregated data, or that there are differences in allocation of individual users or activities to the main sectors or groupings.

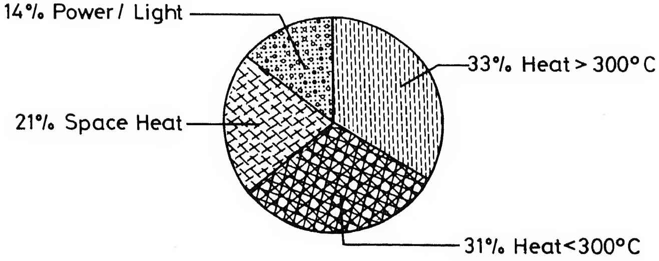
220. The most significant difference between the 'Digest' data and that from the present study is for the iron and steel sector. This originates in a discrepancy between the energy consumption for this industry in the 'Digest'



1980 Energy Consumption by Sector



1980 Energy Consumption by Fuel



1980 Energy Consumption by Final Use

FIGURE 9: Analysis of Energy Consumption in 1980

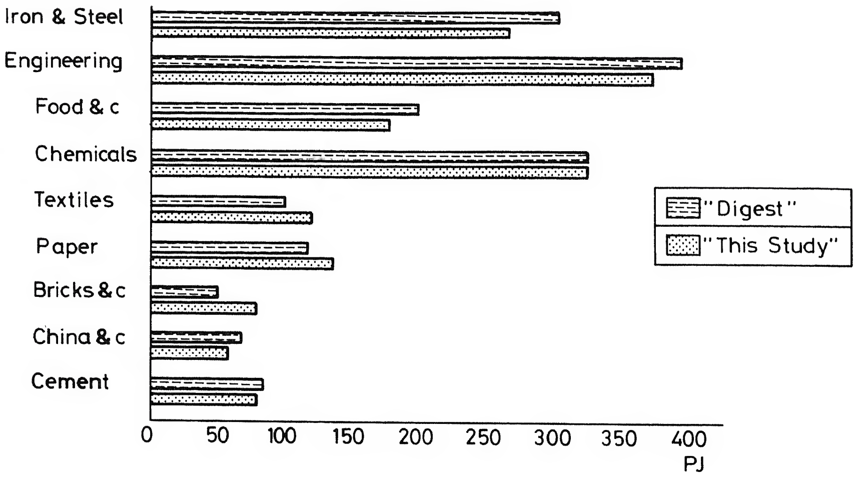


FIGURE 10: Comparison of 1980 Energy Consumption Data from 'Digest of UK Energy Statistics' with This Study, by 'Digest' Main Industrial Groups

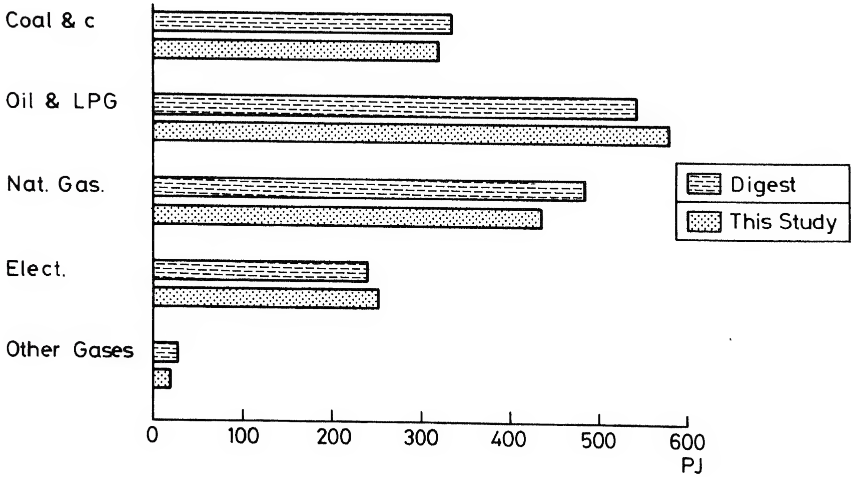


FIGURE 11: Comparison of 1980 Energy Consumption Data from 'Digest of UK Energy Statistics' with This Study, by Fuel

and the statistics published by the Iron and Steel Statistics Bureau, which was the principal source of data on the iron and steel industry for this study. In other sectors, data from the 1979 Purchases Inquiry [ref 17] suggests a surprisingly large use of energy by industry for which no energy audit is available (notably the Conversion of Paper and Board and Other Building Materials). Thus the apparent discrepancies between the 'Digest' data and the data in the present study can only be fully resolved by further research.

ANALYSIS OF PROJECTED IMPROVEMENT IN ENERGY EFFICIENCY

221. The projected improvement in energy efficiency in a given subsector can be readily measured by comparing the estimates of future SEC with the 1980 value of the SEC. It has already been noted that an illustrative figure for total energy consumption in, say, 2000 can be arrived at by multiplying the corresponding values of SEC and output for 2000 from Tables 2 and 3. The energy saving which results from the decrease in SEC can be calculated from the difference between this projected total energy consumption and the energy consumption which would have been obtained if no change in the 1980 value of SEC were assumed (i.e. multiplying the 1980 SEC by the 2000 Output). These sample energy savings can be summed over all the subsectors which allows us to calculate both total energy savings and the average reduction in SEC, weighted by output. However, for the reasons already discussed, these should not be regarded as alternative energy projections. The energy saving in 2000 due to the improvement in energy efficiency derived in this way is:

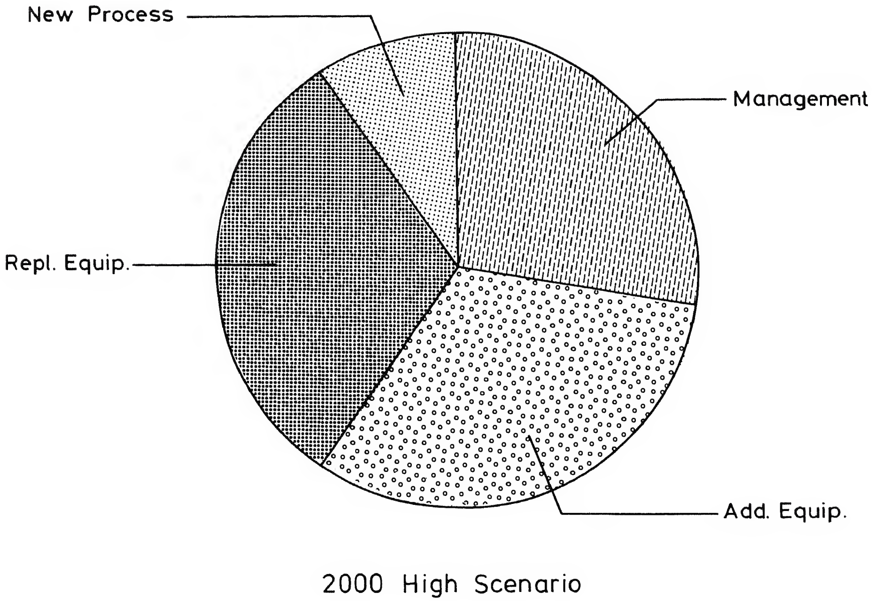
$$\sum \mathrm{SEC}_{(1980)} \times \mathrm{Output}_{(2000)} - \sum \mathrm{SEC}_{(2000)} \times \mathrm{Output}_{(2000)}$$

The results of these calculations are given in Tables 8 and 9 in Annex 4, for the high and low output scenarios respectively. These savings amount to 615 PJ in the high output scenario, which is a reduction of 25.2%, and 417 PJ in the low scenario, a reduction of 20.9%.

222. The energy savings have been broken down into the four categories of energy efficiency measure defined previously (cf. paragraph 30), viz:

- management measures
- additional equipment measures
- replacement equipment measures
- new process technologies.

Figure 12 shows the total energy saving due to each of the four measures. It can be seen that in the high scenario additional and replacement equipment measures each account for about 1/3 of the savings, management measures just over 1/4, and new process technologies 1/10 of the total savings. In the low scenario, the contribution from replacement equipment measures is only 1/4 of the total, which reflects the lower investment in new capacity required to meet the lower output level. The contribution from additional equipment and management measures is proportionately higher than in the high output scenario, whereas the contribution from new process measures is unchanged.



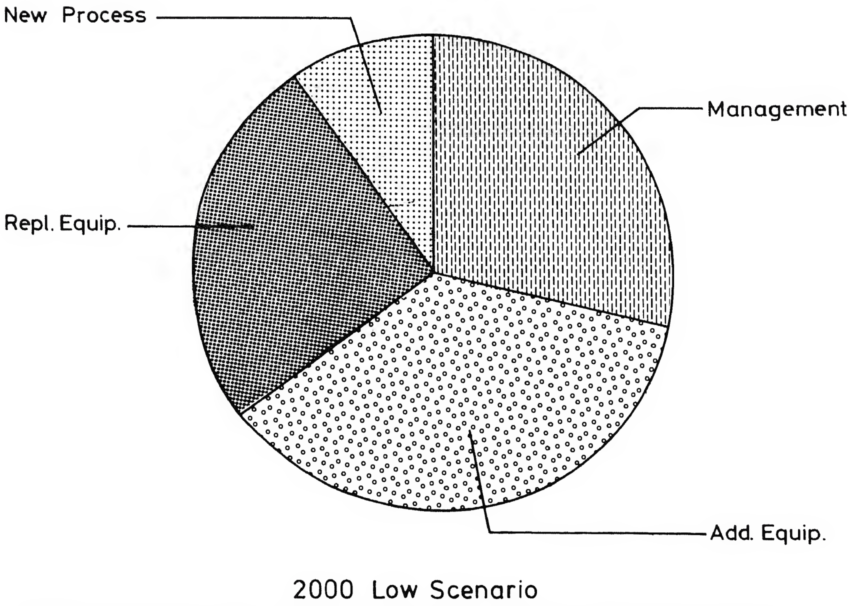
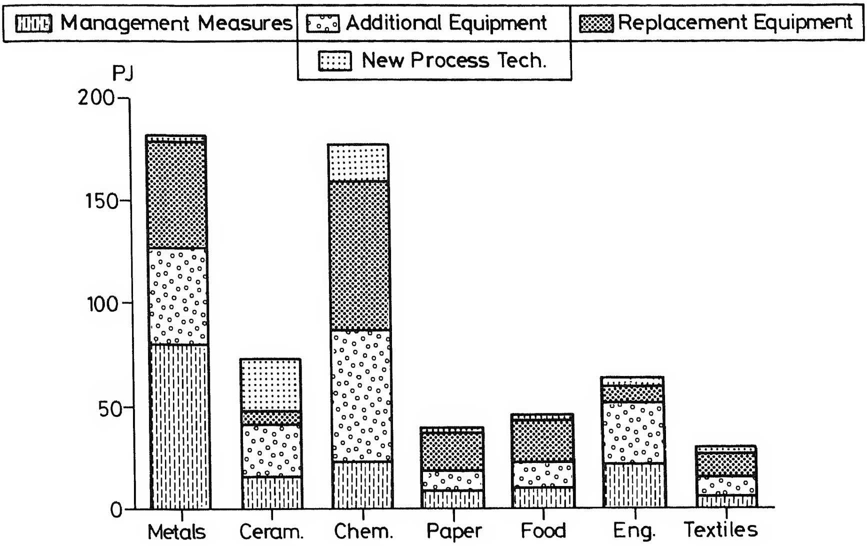
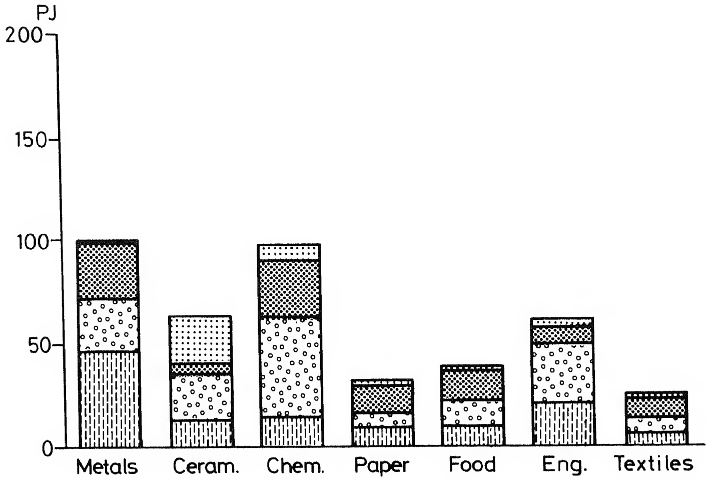


FIGURE 12: Total Energy Saving by Category of Energy Efficiency Measure



2000 High Scenario



2000 Low Scenario

FIGURE 13: Energy Saving by Sector and Category of Energy Efficiency Measure

223. Figure 13 shows the breakdown of the energy savings into categories for each of the main sectors. It can be seen that the largest savings occur in the energy intensive sectors, i.e. metals, ceramics and chemicals, especially in the high scenario. These sectors use substantial amounts of high temperature process heat, which generally offers more scope for cost-effective energy saving measures than other categories of energy use. However, process energy use is more directly related to output than space heating. Hence, in a low output scenario, the opportunities for energy saving in these sectors are proportionately lower than in engineering, in which space heating is the dominant use of energy.

224. Management measures contribute a very high proportion of the energy savings in the metal sector. This is partly because the base year for the study, 1980, was a particularly bad year for energy efficiency in the iron and steel industry due to the effects of a prolonged strike. The analysis of the iron and steel industry in the sector report shows that the specific energy consumption in 1981 was about 15% lower than in 1980; the improvement has been maintained through 1982. The 1980 strike affected energy efficiency adversely because of the need to keep idle plant at high temperatures. However, some of the improvement is due to the retirement of older plant and the more efficient loading of the remaining plant, and there is still considerable scope for further improving energy efficiency in the iron and steel industry through management measures.

225. New process technologies make only a marginal contribution to energy savings, except in the ceramics sector where the introduction of drier processing techniques in cement making are expected to make a major contribution. In general, however, there are not many opportunities for new processes which can be firmly identified as technically and economically viable. Furthermore, the timescale for the development of a major new process from first inception to commercial deployment tends to be rather longer than the time horizon of the present study.

226. For most sectors, the most energy saving is due to a combination of additional equipment measures such as waste heat recovery and replacement equipment measures, in which old inefficient plant is replaced by more modern plant. The latter tends to be more significant in the high output scenario, in which more new capacity is required. In engineering, however, the scope for improving the efficiency of space heating through the replacement of equipment is limited by the relatively long life of buildings and their heating plant compared with process plant. Consequently, improvements in energy efficiency are heavily dependent on the uptake of additional equipment measures, such as insulation and draught-proofing, and management measures such as boiler maintenance, thermostat settings and zoning controls.

COMPARISON WITH ENERGY PAPER 32

227. The assessment of improvements in energy efficiency which are described in the sector reports in Volume II can be compared with the earlier assessment of energy conservation potential in industry given in Energy Paper 32 [ref 2].

228. Figure 14 shows the potential savings expressed as a percentage of total energy consumption for various subsectors, taken from Energy Paper 32. It can be seen that the coverage of individual sectors in Energy Paper 32

FIGURE 14: Data on Energy Conservation Potential from Energy Paper 32 [ref 2]

Sector/Subsector	Total %	Management Measures %	Additional Equipment Measures %	Replacement Equipment Measures %	New Process Technologies %
Metal Manufacturing					
Iron and Steel	34	5	11		18
Aluminium (smelting)	61			24	56
Copper)	29	7	7		15
Lead and Zinc)					
Ceramic Materials					
Cement	36	7	10		19
Bricks	58	6	17		35
Refractories	28	5	16		7
Potteries	10		10		
Glass	15	1	1		13
Miscellaneous					
Chemicals					
Inorganic (chlor-alkali)	13				
Organic					
Fertilisers	39	2	2		35
Polymers					
Dyestuffs					
Paints					
Pharmaceuticals					
Detergents					
Miscellaneous					
Paper					
Paper and Board Making	30		8	11	11
Conversion of Paper					
Printing and Publishing					
Food, etc.					
Dairy (10^6 ℓ milk; MJ/ℓ)	14	5	4		5
Processed Foods					
Bakery					
Sugar					
Drink					
Oils and Fats					
Miscellaneous					
Tobacco					
Engineering					
Mechanical					
Instruments					
Electrical	12	3.5	3.5	5	
Vehicles, etc.					
Metal Goods					
Textiles					
Wool					
Cotton					
Knitted Goods					
Textile Finishing					
Jute and Carpets					
Miscellaneous Textiles					
Synthetic Fibres					
Leather					
Footwear and Clothing					
Other Industries	16				
Overall	29				

was quite sparse, reflecting the relatively few reports in the Audit [ref 3] and Thrift [ref 4] series which were available when Energy Paper 32 was written in 1978. The present study, on the other hand, had access to a much more complete set of reports (listed in Annexes 1 and 2). Many of the earlier Audit and Thrift reports are now somewhat dated, but the sector reports in Volume II have taken account of recent trends, especially in the 1979-1982 period. Thus, the present study represents a fuller, up-to-date assessment of the prospects for energy conservation in industry.

229. Energy Paper 32 was only concerned with 'technological potential', whereas in this study we are concerned with tentatively projecting the possible uptake through to 2000. Nevertheless, it is interesting to note that in areas in which Energy Paper 32 includes suitable data the 'technological potential' is fairly close to the uptake by 2000. For example, in bricks, cement, glass and refractories, the technological potential is only a few percentage points higher than the uptake by 2000, suggesting that most of the potential is expected to be taken up by 2000.

230. In the breakdown of the potential by category of conservation measure, there are some differences between the present study and Energy Paper 32, which possibly stem from different definitions of the categories. For example, continuous casting in the iron and steel industry may have been classified in Energy Paper 32 as a new process technology in the iron and steel industry; in the present study it is regarded as a replacement equipment measure.

231. In general, there appears to be less uptake of new process technology in the present projections than is identified in the technological potential from Energy Paper 32. This is to be expected because the timescale for adopting new technologies, such as the ALCOA aluminium smelting process, is longer than for the other measures.

232. The overall assessment of energy saving potential in industry was 29%. Thus, the present estimate of 21-25% saving by 2000, depending on scenario, is compatible with the original assessment of technical potential, and implies that a substantial proportion of the technical potential could be taken up by 2000.

EVALUATION OF OUR FINDINGS

233. The preparation of a complete set of future energy demand projections for the industrial sector would have involved taking full account of the likely range of variation in all the factors which affect industrial energy demand including alternative paths for future energy prices, the growth and structure of industrial output and the relations between these variables. Such an exercise is not feasible using specific energy consumptions. As explained in Chapter 4 it has not been possible to assess the impacts of variations in energy prices or of substantial changes in rates of growth of industrial sectors on SECs. We concluded therefore that the method used in this study did not provide projections comparable to those in Energy Projections 1982 but one potential input to a model from which industrial energy demand could be derived.

234. The highly tentative illustrative calculations using output assumptions derived from the two middle cases in the 1982 Energy Projections can in our

judgement, therefore, do no more than show that the results of our work do not provide any reason to cast doubt on the 1982 Projections.

235. Our illustrative calculations of future energy consumption in each of the main sectors are shown in Figure 15. In the sample high output scenario, total energy consumption increases from 1,607 PJ in 1980 to 1,670 PJ in 1990 and 1,820 PJ in 2000. In the low output scenario, total energy consumption falls slightly to 1,575 PJ in 1990 and 1,580 PJ in 2000. The detailed numerical data for each subsector are shown in Tables 10-13 in Annex 4.

236. Figures 16-18 show the pattern of energy use projected for 2000 broken down by sector, by fuel and by final use for each scenario; these can be compared with the 1980 pattern shown previously in Figure 9.

237. There are only slight variations in the relative proportions of energy consumption by each sector shown in Figure 16. Thus, in the high output scenario, chemicals and engineering account for a somewhat higher proportion of total energy consumption, metal manufacturing is unchanged and the other sectors decline slightly. In the low output scenario, on the other hand, only engineering increases its total share. These slight variations reflect differences in both the structure of output and the improvement in energy efficiency. For example, engineering offers the least scope for improving energy efficiency and, in the low output scenario, tends to increase its share of total output at the expense of the more energy intensive sectors.

238. The market share of coal, etc. (mainly coal and coke, but including a small contribution from biofuels and coke-oven gas) shown in Figure 17 increases from 21% of total energy consumption in 1980 to 36% in 2000 in the high scenario and 31% in the low scenario. Electricity increases its share from 16% in 1980 to 19% in 2000 in both scenarios. Petroleum, on the other hand, declines from 36% in 1980 to 19% in 2000 in the high scenario and 21% in the low scenario. The market share of natural gas decreases slightly in the high scenario, from 27% in 1980 to 26% in 2000, while in the low scenario it increases slightly, to 28% by 2000.

239. The breakdown of energy consumption by final use (Figure 18) shows a small decrease in the proportion of high temperature process heat, which reflects a greater scope for improvement in energy efficiency in high temperature processes, and a corresponding increase in the proportion of space heating.

240. It has already been noted (cf. paragraph 90) that the two scenarios in the present study correspond to the industrial output assumptions of the upper middle (YU/BU) and lower middle (YL/BL) scenarios from the Department of Energy's 1982 Energy Projections [ref 1]. The sample estimates from the present study are compared with the corresponding 1982 Energy Projections in Figure 19 for the high output scenario and Figure 20 for the low output scenario. The numerical data for these figures is given in Tables 19 and 20. Figures 19 and 20 also show the energy consumption which would result if there were no improvement in energy efficiency; this is calculated by combining the projected future output with the 1980 specific energy consumption (cf. Tables 19-22).

241. For both scenarios, the estimates of total energy consumption in this study are slightly less than the totals in the corresponding 1982 Energy

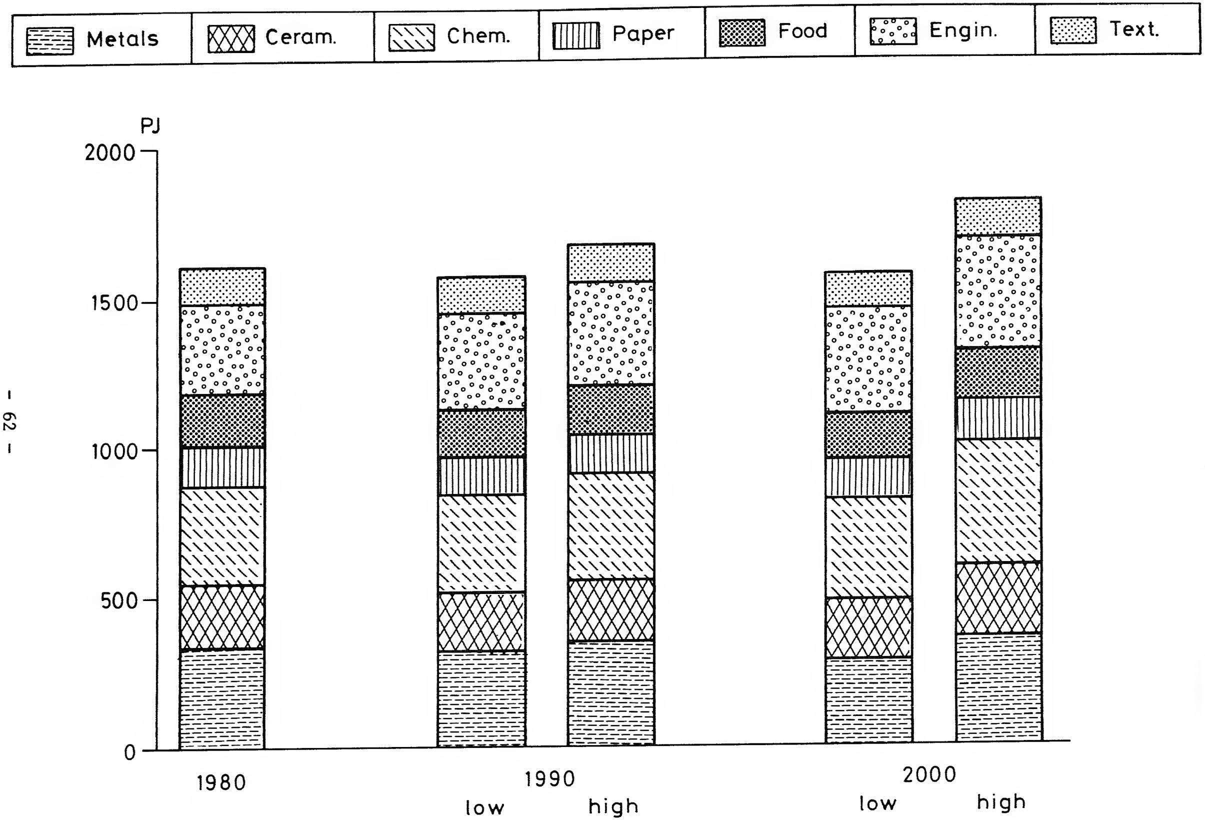


FIGURE 15: Illustrative Future Energy Consumption by Sector

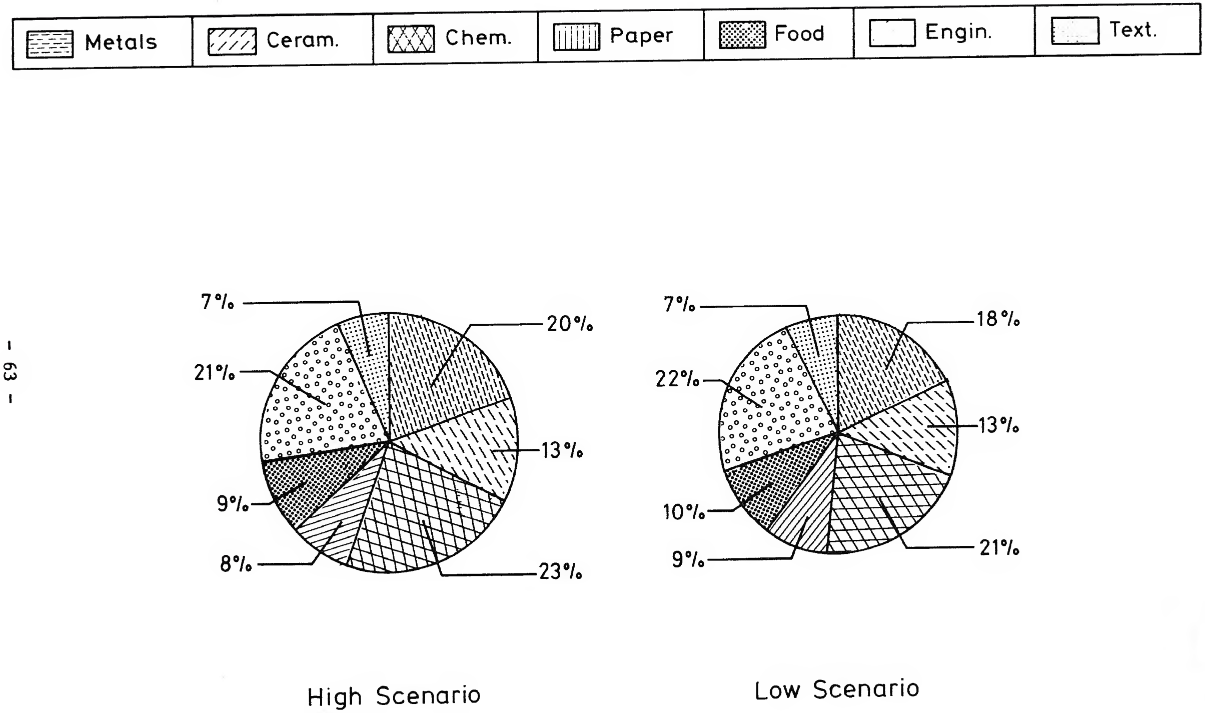


FIGURE 16: Illustrative Energy Consumption in 2000 by Sector

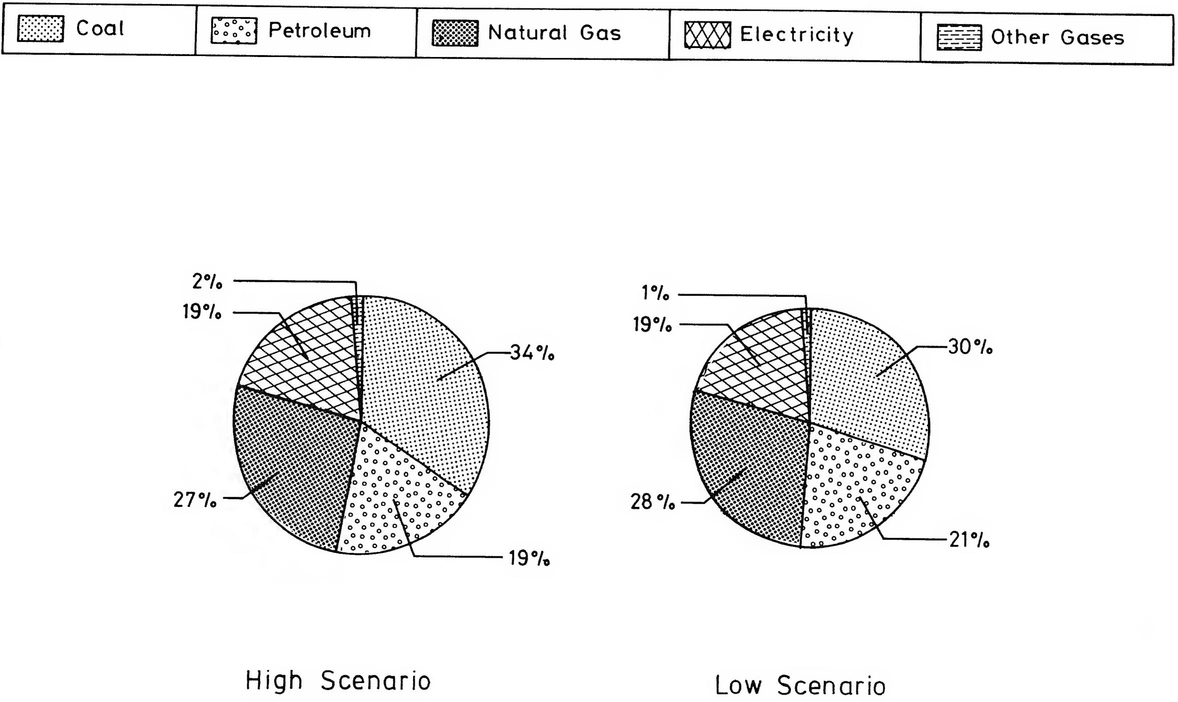


FIGURE 17: Illustrative Energy Consumption in 2000 by Fuel

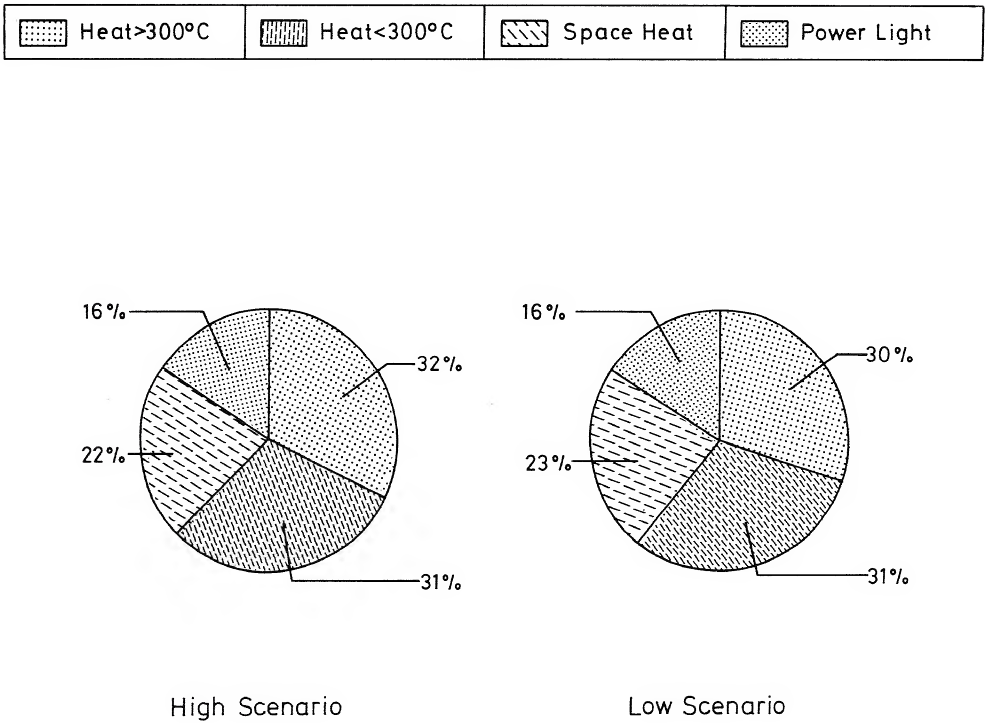


FIGURE 18: Illustrative Energy Consumption in 2000 by Final Use

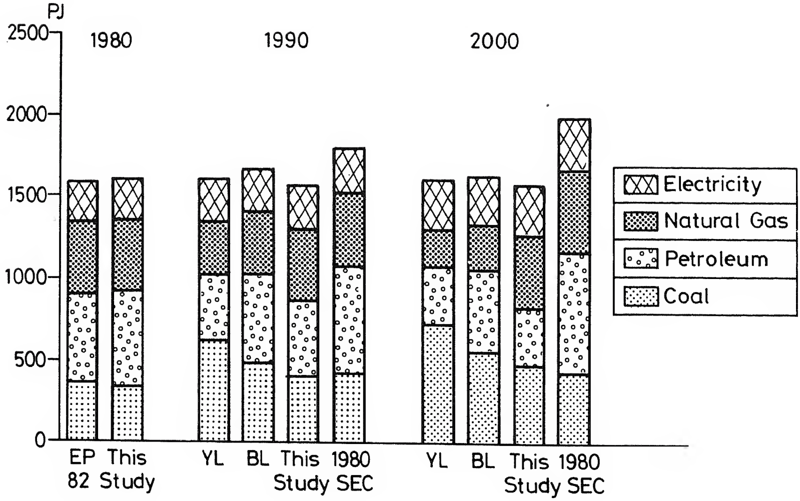


FIGURE 19: Comparison with 1982 Energy Projections
High Output Scenario

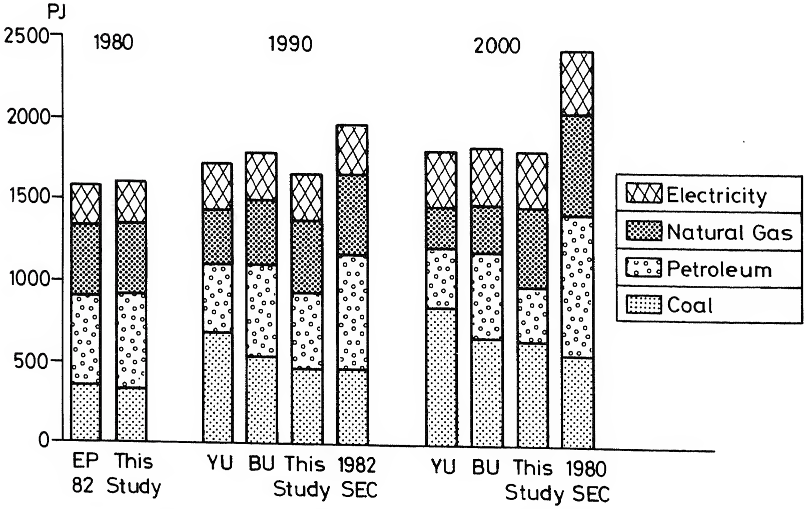


FIGURE 20: Comparison with 1982 Energy Projections
Low Scenario

Projections. The difference is more noticeable in the 1990 figures than in the 2000 figures. Thus, in the high output scenario, the total energy consumption in the present study for 1990 is 62 PJ lower than the YU scenario and 119 PJ lower than the BU scenario out of a total consumption of over 1,600 PJ in these scenarios; for 2000 it is 4 PJ lower than YU and 22 PJ lower than BU. A similar trend is observed in the low output scenario. This suggests that the present study anticipates a somewhat faster initial uptake of energy conservation potential than the 1982 Energy Projections. This is because the latter assume a 'kinked' pathway for future energy prices, with sharper increases after 1990; the present study does not model this effect.

242. In both scenarios, the estimates in this study estimate a 19% share of electricity in the fuel mix by 2000, which is about the same as the 1982 Energy Projections. The 1980 share of electricity was 16%. Electricity has an increased market share partly because the expected improvements in energy efficiency are predominantly in the use of fossil fuels for process heat and space heating. It is also assumed that there is a trend towards increased use of motive power for continuous or automated processes, and to a lesser extent in direct process heating (e.g. induction furnaces).

243. The present study does not make any specific assumptions about fuel prices; changes in fuel mix are determined by a broad assumption that there will be a progressive substitution of coal for oil and gas where coal is a technically acceptable alternative, but that gas will tend to retain or increase its market share where its qualities as a premium fuel and high end-use efficiency can offset the high price assumed by the 1982 Energy Projections. This effect accounts for most of the difference compared with the 1982 Energy Projections and is subject to considerable uncertainty. The share of coal and oil is lower, and that of gas higher, in the present study compared with the 1982 Energy Projections, especially for the YU and YL scenarios. The YU and YL scenarios differ from the BU and BL scenarios in their assumptions about world oil prices; the former assume higher prices for oil relative to coal, which causes a greater shift to coal.

244. Comparison of the projected total energy consumption in this study with the total energy consumption which would result from unchanged 1980 SEC values shows that there is an improvement in energy efficiency in the high output case of 16% by 1990 and 25% by 2000; in the low output case the improvement is 13% by 1990 and 21% by 2000. The improvements in energy efficiency are correspondingly lower for the 1982 Energy Projections, reflecting the somewhat higher total energy consumption. For example, for the YU scenario, the improvement is 23% by 2000; for the YL scenario it is 18% by 2000.

245. Bearing in mind the uncertainties inherent in the present study and in the Department's Energy Projections, we feel justified in claiming some support for our methodology and for the conclusions that we have reached concerning the realistic opportunities for improving the efficiency of energy utilisation in manufacturing industry. Our methodology, although it contains considerable uncertainties, uses most of the currently available information on the required level of detail and leads us to the conclusion that improved energy efficiency could lead to a significant saving in our future energy requirements. As more basic information becomes available, these estimates can be improved. Nevertheless, they remain estimates only; they are not intentions, programmes, projections, forecasts, targets or requirements. It will remain for other studies to decide on how they might best be achieved.

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ANNEX 1

PUBLICATIONS IN THE ENERGY AUDIT SERIES

Published

1. The Iron Casting Industry
2. The Building Brick Industry
3. The Dairy Industry
4. The Bulk Refractories Industry
5. The Glass Industry
6. The Aluminium Industry
7. The Pottery Industry
8. The Brewing Industry
9. The Coke Making Industry
10. The Zinc and Lead Industries
11. The Cement Industry
12. The Copper Industry
13. The Fertilizer Industry
14. The Paper and Board Industry
15. The Malting Industry
16. The Iron and Steel Industry
17. The Textile Industry
19. Industrial Paint Finishing
21. The Oil Refining Industry

In Preparation

The Mechanical Engineering Industry

ANNEX 2

PUBLICATIONS IN THE INDUSTRIAL ENERGY THRIFT SERIES

Report No	Industry/Sector
1.	Woollen and worsted
2.	Pottery
3.	Bricks, fireclay and refractory goods
4.	Shipbuilding and marine engineering
5.	Abrasives and miscellaneous building materials
6.	Spinning and doubling (cotton system)
7.	Stationery printing
8.	Newspaper and magazine printing
9.	Paper
10.	Soap and detergents
11.	Copper
12.	Lead, zinc and other base metals
13.	Weaving (cotton system)
14.	Electrical engineering
15.	Timber, furniture and related industries
16.	Knitting
17.	Plastics (MLH 276)
18.	Miscellaneous chemical manufacturing
19.	Pharmaceutical chemicals and toilet preparations
20.	Textile finishing
21.	Mechanical engineering
22.	Footwear, leather and fur
23.	Glass
24.	Dyestuffs and pigments
25.	Cans, cutlery, engineers' small tools, hand tools, nuts, bolts, wire and wire products
26.	Motor vehicles, aerospace and railways
27.	Rubber, and linoleum and plastics floor-coverings
28.	Steelfoundry
29.	Gramophone records, sound reproducing equipment, electronic capital goods
30.	Carpets and jute
31.	Tobacco
32.	Meat, fish, fruit and vegetable processing
33.	Fertilizers
34.	Ironfounding
35.	General chemicals
36.	Aluminium
37.	Mechanical engineering
38.	Manufacturing industry in Northern Ireland
39.	General printing and publishing
40.	Private steel
41.	Man-made fibres
42.	Milling, mixing and edible fat processing
43.	Paint manufacture
44.	Miscellaneous textiles
45.	Made-up clothing
46.	Miscellaneous including hardware and leisure products
47.	Confectionery

Report No	Industry/Sector
48.	Baking
49.	Dairy and alcoholic and soft drinks
50.	Instrument engineering
51.	Metal goods

The report entitled 'A Preliminary Analysis of the Potential for Energy Conservation in Industry' is also included in this Series.

ANNEX 3

ORGANISATIONS CONTACTED IN THE PREPARATION OF THIS REPORT

Iron and Steel Industry

Mr R Mayorcas, Consultant, Chester
BSC Grangetown Laboratory, Teeside.
BSC Welsh Laboratory, Port Talbot.

Non-ferrous Metals

British Alcan Aluminium, Lynemouth.
British Alcan Aluminium, Letchford Lock, Warrington.
British Alcan Aluminium, Chalfont Technological Centre.
Aluminium Federation, Birmingham.
IMI Yorkshire Imperial Ltd, Copper Tube Division, Leeds.
BICC Prescot Rod Rollers, Prescot.
BNF Metals Technology Centre.
Lead and Zinc Development Association.
Mr J D Kirby, Consultant, Solihull.

Cement Industry

Blue Circle Industries PLC.
Rugby Portland Cement PLC.
RTZ Tunnel Cement Ltd.
RTZ Ketton Cement Ltd.
Cement Manufacturers' Federation.

Brick Industry

British Ceramic Research Association Ltd.

Pottery Industry

British Ceramic Manufacturers' Federation.
British Ceramic Research Association.

Glass Industry

British Glass Industry Research Association.
British Gas Corporation, Midlands Research Station.

Refractories Industry

The Refractories Association of Great Britain.
Unicorn Industries PLC, Electro Minerals and Media Group.
J&J Dyson Ltd.
GR-Stein Refractories Ltd.
Streetley Refractories Ltd.

Chemical Industries

Chemical Industries Association.
Rubber and Plastics Research Association.
ICI PLC.

Food, Drink and Tobacco

United Biscuits PLC.
Brewers Society.
Campden Food Preservation Research Association.
Leatherhead Food Research Association.
Flour, Baking and Grain Milling Research Association.
Food Economics Unit, MAFF.
Food Science Division, MAFF.
British Bakeries PLC.
Tate and Lyle Ltd.
British Sugar PLC.
Food Manufacturers Federation Inc.
Cadbury Schweppes PLC.
Marfleet Refining PLC.
Anglia Canning PLC.

Engineering

PERA.
ERA Technology Ltd.
National Engineering Laboratory.
Engineering Employers Federation.

Textiles

Shirley Institute.
National Engineering Laboratory.

Paper and Board

British Paper and Board Industry Federation.
Printing Industry Research Association.
National Engineering Laboratory.

Miscellaneous

National Economic Development Office.
Department of Trade and Industry.

ANNEX 4

TABULAR PRESENTATION OF RESULTS

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22. Energy Consumption in 2000, Low Output Scenario, Using 1980 SEC

23. Data on Energy Conservation Potential from Energy Paper 32 [ref 2]

Note: With the exception of Table 1, which is based on data from the 1979 Purchases Inquiry, the data in these tables are constructed by combining data on energy consumption patterns taken from the sector reports in Volume II of this report with corresponding output levels.

Data for 1980 are derived from a variety of sources, as described in paragraph 218. Comparisons with the Digest of UK Energy Statistics show a number of discrepancies, which are discussed in paragraph 220.

Estimates of future specific energy consumption and fuel mix are based on considerations of expected trends in both industry structure and improvements in energy efficiency. These are, of course, qualified by considerable uncertainties in the various assumptions made, as detailed in the sector reports.

TABLE 1: Analysis of Energy Intensities of Subsectors (1979 Purchases Inquiry data, ref 17)

Sheet 1

	Energy Consumption	Physical Output	Monetary Output Gross	Monetary Output Net	Energy Purchases	Total Purchases	Energy / Physical Output	Energy / Gross Output	Energy / Net Output	Energy Purchases / Total Purchases	Energy Purchases / Net Output
	(PJ)	10^6 tonne	(£M)	(£M)	(£M)	(£M)	(GJ/tonne)	(MJ/£)	(MJ/£)	(%)	(%)
Metals Manufacturing											
Iron & Steel	521	21.46	7,780	2,194	951	5,377	24.3	66.7	237	17.7	43.3
Aluminium	41.6	0.57	1,130	303	n.a.	695	73.0	36.8	137	n.a.	n.a.
Copper	10.1	0.62	950	303	29	606	16.3	10.6	33.3	4.8	9.8
Other Non-ferrous	17.9	0.68	1,437	346	47	916	26.3	12.5	51.7	5.1	13.6
Total	590.6	23.3	11,297	3,146		7,594	25.3	52.3	187.7		
Ceramic Materials											
Bricks	29.8	9.8	385	244	62	115	3.0	77.4	122	53.7	25.4
Cement	115	16.1	618	364	161	239	7.1	186	315	67.4	44.2
Glass	54.1	3.1	1,088	630	112	396	17.5	49.7	85.9	28.3	17.8
Refractories	14.6	1.2	277	128	26	137	12.2	52.7	114	19.0	20.3
Potteries	19.2	n.a.	591	388	42	171	n.a.	32.5	49.5	24.6	10.8
Misc. Building Mat.	54.1	n.a.	2,873	1,478	154	1,208	n.a.	18.8	36.6	12.7	10.4
Total	286.8		5,832	3,232	557	2,266		49.2	88.7	24.6	17.2
Chemicals											
Bulk Organic	144*	4.27	3,635	875	250	2,245	33.7	39.6	165	11.1	28.6
Bulk Inorganic	63.4		1,274	442	168	739		49.8	143	22.7	38.0
Fertilisers	22.5	2.80	956	402	51	439	8.0	23.5	56.0	11.6	12.7
Other	124		10,378	4,376	297	5,031		11.9	28.3	5.9	6.8
Total	353.9		16,243	6,095	766	8,454		21.8	58.1	9.1	12.6
Paper, etc.											
Paper & Board Making	102	4.25	1,551	551	184	960	24.0	65.8	185	19.2	33.4
Conversion of Paper & Board	25.4		3,363	1,676	67	1,519		7.6	15.2	4.4	4.0
Printing & Publishing	19.1		5,823	3,550	60	1,634		3.3	5.4	3.7	1.7
Total	146.5		10,737	5,777	311	4,113		13.6	24.4	7.6	5.4

* Excluding feedstock petroleum and natural gas

TABLE 1: Analysis of Energy Intensities of Subsectors (1979 Purchases Inquiry data, ref 17)

Sheet 2

	Energy Consumption (PJ)	Physical Output 10^6 tonne	Monetary Output Gross (£M)	Monetary Output Net (£M)	Energy Purchases (£M)	Total Purchases (£M)	Energy / Physical Output (GJ/tonne)	Energy / Gross Output (MJ/£)	Energy / Net Output (MJ/£)	Energy Purchases / Total Purchases (%)	Energy Purchases / Net Output (%)
Food, Drink & Tobacco											
Oils & Fats	9.0	3.01	965	141	17.8	720	3.0	9.3	63.8	2.5	12.6
Dairy	24.5		3,527	622	65.9	2,477		6.9	39.4	2.7	10.6
Bakery	26.0	2.93	3,396	1,163	77.7	1,877	8.9	7.7	22.4	4.1	6.7
Sugar, etc.	33.2	3.22	2,672	962	58.8	1,461	10.3	12.4	34.5	4.0	6.1
Processed Foods	24.9		4,053	1,139	78.6	2,606		6.1	21.9	3.0	6.9
Drink	58.4		6,409	2,193	142	3,369		9.1	26.6	4.2	6.5
Tobacco	4.7	0.145	3,885	657	10.8	2,979	32.4	1.2	7.1	0.4	1.6
Miscellaneous	33.8		5,282	1,401	87.1	3,353		6.4	24.1	2.6	6.2
Total	214.5		30,189	8,278	538.7	18,842		7.1	25.9	2.8	6.5
Textiles											
Wool	14.2	n.a.	1,292	444	37.2	739	n.a.	11.0	32.0	5.0	8.4
Cotton	11.2	"	1,138	427	38.0	640	"	9.8	26.2	5.9	8.9
Knitted Goods	13.7	"	1,349	666	27.9	585	"	10.2	20.6	4.8	4.2
Finishing	24.0	"	456	252	48.6	187	"	52.6	95.2	26.0	19.3
Carpets & Jute	11.1	"	846	315	23.8	472	"	13.1	35.2	5.0	7.6
Misc. Textiles	3.3	"	406	182	9.7	187	"	83.3	18.6	5.2	5.3
Leather, Footwear & Clothing	20.5	"	5,383	2,448	62.6	2,487	"	3.8	8.4	2.5	2.6
Man-made Fibres	29.6	"	875	305	69.7	512	"	33.8	97.0	13.6	22.9
Total	127.6		11,745	5,039	317.5	5,809		10.9	25.3	5.5	6.3
Engineering											
Metal Goods	152	n.a.	8,266	3,962	303	3,854	n.a.	18.4	38.4	7.9	7.6
Mechanical	99.5	"	18,033	9,148	305	7,213	"	5.5	10.9	4.2	3.3
Electrical	63.5	"	12,982	6,438	193	5,438	"	4.9	9.9	3.5	3.0
Vehicles & Transport Equipment	131	"	16,718	7,018	360	7,780	"	7.8	18.7	4.6	5.1
Instruments	6.4	"	1,542	782	21	617	"	4.2	8.2	3.4	2.7
Total	452.4		57,541	27,348	1,182	24,902		7.9	16.5	4.7	4.3

TABLE 2: Illustrative Assumptions on Output (kilotonnes or £M per year)* and Specific Energy Consumption (GJ/tonne or GJ/£k)*, High Scenario

Sector/Subsector	1980		1990		2000	
	Output	SEC_{AV}	Output	SEC_{AV}	Output	SEC_{AV}
Metal Manufacturing	(kt)	(GJ/t)	(kt)	(GJ/t)	(kt)	(GJ/t)
Iron & Steel	11,277	23.6	16,500	17.2	18,900	15.1
Aluminium	504	93.0	600	82.0	760	75.0
Copper	530	16.8	580	14.3	670	11.8
Lead and Zinc	550	21.6	640	19.1	800	17.0
Ceramic Materials	(kt)	(GJ/t)	(kt)	(GJ/t)	(kt)	(GJ/t)
Cement	13,880	5.71	15,030	4.38	18,680	3.82
Bricks	9,160	2.08	10,630	1.68	13,210	1.60
Refractories	820	12.60	1,200	10.56	1,370	9.65
Potteries (£M; GJ/£k)	629	22.5	570	14.3	710	11.6
Glass (kt; GJ/t)	2,900	14.66	3,370	12.76	4,190	12.49
Misc. Building Materials (£M; GJ/£k)	3,148	15.6	3,790	14.5	4,790	13.3
Chemicals	(£M)	(GJ/£k)	(£M)	(GJ/£k)	(£M)	(GJ/£k)
Inorganic	1,298	42.8	1,580	37.2	2,120	31.2
Organic	3,410	39.3	4,370	33.8	6,140	27.5
Fertilisers	957	24.7	1,170	21.5	1,560	18.0
Polymers	1,649	11.9	2,110	10.2	2,970	8.4
Dyestuffs	674	29.8	820	25.9	1,100	21.2
Paints	1,185	4.0	1,450	3.5	1,940	2.9
Pharmaceuticals	2,442	6.3	3,970	5.0	7,810	4.0
Detergents	1,529	3.2	1,960	2.8	3,030	2.2
Miscellaneous	3,385	13.6	4,550	11.6	6,710	9.5
Paper						
Paper & Board Making (kt; GJ/t)	3,817	24.4	4,200	19.0	5,150	18.0
Conversion of Paper (£M; GJ/£k)	3,589	6.5	4,100	6.0	4,950	5.5
Printing & Publishing (£M; GJ/£k)	6,798	2.8	7,800	2.7	8,800	2.5
Food, etc.	(kt)	(GJ/t)	(kt)	(GJ/t)	(kt)	(GJ/t)
Dairy (10^6 ℓ milk; MJ/ℓ)	15,214	1.54	18,060	1.45	18,560	1.33
Processed Foods	5,173	4.16	5,520	3.75	5,950	3.28
Bakery**	8,661	1.81	8,630	1.68	8,650	1.58
Sugar	3,475	7.70	3,500	6.40	3,550	6.20
Drink	15,794	3.37	19,140	2.86	23,530	2.53
Oils & Fats	2,144	6.37	2,220	6.00	2,310	5.63
Miscellaneous	13,860	1.43	15,840	1.19	18,300	0.97
Tobacco	150	13.82	155	13.09	160	12.21
Engineering	(£M)	(GJ/£k)	(£M)	(GJ/£k)	(£M)	(GJ/£k)
Mechanical	19,170	3.85	22,290	3.56	25,560	3.27
Instruments	1,782	3.61	2,290	3.35	2,920	3.10
Electrical	14,526	3.34	18,620	3.05	23,810	2.77
Vehicles, etc.	17,838	6.36	21,640	5.92	26,290	5.47
Metal Goods	8,452	7.31	10,310	6.81	11,270	6.31
Textiles	(£M)	(GJ/£k)	(£M)	(GJ/£k)	(£M)	(GJ/£k)
Wool	1,155	11.59	1,280	10.43	1,410	9.27
Cotton	1,081	11.17	1,140	9.88	1,200	8.93
Knitted Goods	1,258	6.76	1,460	5.96	1,700	5.47
Textile Finishing	380	56.37	440	50.74	510	45.10
Jute & Carpets	688	15.15	800	13.41	930	12.12
Miscellaneous Textiles	578	9.22	670	8.26	780	7.30
Synthetic Fibres	693	48.79	730	43.91	770	39.03
Leather Goods	420	10.21	510	8.45	620	7.15
Footwear & Clothing	4,827	2.28	5,890	1.89	7,170	1.60

* Output measure in gross monetary value for Chemicals, Engineering, Textiles and parts of Ceramic Materials and Paper.

** Excluding flour confectionery.

TABLE 3: Illustrative Assumptions on Output (kilotonnes or £M per year)* and Specific Energy Consumption (GJ/tonne or GJ/£k)*, Low Scenario

Sector/Subsector	1980		1990		2000	
	Output	SEC_{AV}	Output	SEC_{AV}	Output	SEC_{AV}
Metal Manufacturing	(kt)	(GJ/t)	(kt)	(GJ/t)	(kt)	(GJ/t)
Iron & Steel	11,277	23.6	13,700	18.4	12,500	16.5
Aluminium	504	93.0	590	87.0	700	83.0
Copper	530	16.8	560	15.1	620	13.4
Lead and Zinc	550	21.6	610	20.7	700	18.3
Ceramic Materials	(kt)	(GJ/t)	(kt)	(GJ/t)	(kt)	(GJ/t)
Cement	13,880	5.71	14,590	4.42	16,930	3.82
Bricks	9,160	2.08	10,120	1.72	11,740	1.75
Refractories	820	12.60	980	10.56	890	9.65
Potteries (£M; GJ/£k)	629	22.5	550	14.3	630	11.6
Glass (kt; GJ/t)	2,900	14.66	3,200	12.76	3,710	12.49
Misc. Building Materials (£M; GJ/£k)	3,148	15.6	3,640	14.5	4,270	13.3
Chemicals	(£M)	(GJ/£k)	(£M)	(GJ/£k)	(£M)	(GJ/£k)
Inorganic	1,298	42.8	1,360	38.5	1,430	34.7
Organic	3,410	39.3	3,770	35.0	4,160	31.0
Fertilisers	957	24.7	1,010	22.2	1,060	20.0
Polymers	1,649	11.9	1,820	10.6	2,010	9.4
Dyestuffs	674	29.8	750	26.5	910	22.9
Paints	1,185	4.0	1,310	3.6	1,600	3.1
Pharmaceuticals	2,442	6.3	3,620	5.2	5,890	4.2
Detergents	1,529	3.2	1,690	2.8	2,060	2.5
Miscellaneous	3,385	13.6	4,130	11.8	5,550	9.9
Paper						
Paper & Board Making (kt; GJ/t)	3,817	24.4	4,000	20.0	4,600	19.0
Conversion of Paper (£M; GJ/£k)	3,589	6.5	4,000	6.0	4,600	5.5
Printing & Publishing (£M; GJ/£k)	6,798	2.8	7,700	2.7	9,500	2.5
Food, etc.	(kt)	(GJ/t)	(kt)	(GJ/t)	(kt)	(GJ/t)
Dairy (10^6 ℓ milk; MJ/ℓ)	15,214	1.54	17,530	1.40	18,030	1.37
Processed Foods	5,173	4.16	5,270	3.64	5,410	3.17
Bakery**	8,661	1.81	8,200	1.65	7,830	1.54
Sugar	3,475	7.70	3,360	6.40	3,250	6.20
Drink	15,794	3.37	17,870	2.88	20,490	2.63
Oils & Fats	2,144	6.37	2,150	5.98	2,160	5.59
Miscellaneous	13,860	1.43	15,110	1.24	16,620	1.06
Tobacco	150	13.82	150	13.09	145	12.21
Engineering	(£M)	(GJ/£k)	(£M)	(GJ/£k)	(£M)	(GJ/£k)
Mechanical	19,170	3.85	21,180	3.56	23,380	3.27
Instruments	1,782	3.61	2,290	3.35	2,920	3.10
Electrical	14,526	3.34	18,620	3.05	23,810	2.77
Vehicles, etc.	17,838	6.36	20,620	5.92	23,550	5.47
Metal Goods	8,452	7.31	9,830	6.81	11,270	6.31
Textiles	(£M)	(GJ/£k)	(£M)	(GJ/£k)	(£M)	(GJ/£k)
Wool	1,155	11.59	1,220	10.72	1,280	9.85
Cotton	1,081	11.17	1,080	9.88	1,080	8.93
Knitted Goods	1,258	6.76	1,390	6.04	1,540	5.63
Textile Finishing	380	56.37	420	52.14	460	47.91
Jute & Carpets	688	15.15	760	13.41	840	12.12
Miscellaneous Textiles	578	9.22	640	8.53	710	7.84
Synthetic Fibres	693	48.79	690	45.13	690	41.47
Leather Goods	420	10.21	490	9.04	570	8.17
Footwear & Clothing	4,827	2.28	5,610	1.89	6,520	1.60

* Output measure in gross monetary value for Chemicals, Engineering, Textiles and parts of Ceramic Materials and Paper.

** Excluding flour confectionery.

TABLE 4: 1980 Energy Consumption by Fuel Type (PJ)

Sector/Subsector	Total	Coal + Coke	Oil + LPG	Nat. Gas	Elec.	Other Gases
Metal Manufacturing						
Iron & Steel	266.1	126.0	51.5	42.7	27.6	18.3
Aluminium	47.0	1.9	11.3	8.0	25.8	
Copper	8.9	0.5	1.9	4.3	2.2	
Lead and Zinc	11.9	3.7	3.8	2.6	1.8	
Total	333.9	132.1	68.5	57.6	57.4	18.3
Ceramic Materials						
Cement	79.2	70.9	1.4	0.8	6.1	
Bricks	19.0	3.8	6.6	6.4	1.2	1.0
Refractories	10.3	2.7	2.9	4.1	0.6	
Potteries	14.1	0.2	3.7	9.0	1.2	
Glass	42.5	-	21.9	16.7	3.9	
Misc. Building Materials	49.1	3.9	33.7	5.2	6.3	
Total	214.2	81.5	70.2	42.2	19.3	1.0
Chemicals						
Inorganic	55.5	3.1	23.3	18.2	10.9	
Organic	133.9	0.7	58.7	66.8	7.7	
Fertilisers	23.6	0.4	4.2	14.4	4.6	
Polymers	19.6	1.4	8.2	4.3	5.7	
Dyestuffs	20.1	4.9	6.7	6.5	2.0	
Paints	4.7	0.1	1.9	1.9	0.8	
Pharmaceuticals	15.4	-	6.3	6.1	3.0	
Detergents	4.9	0.4	1.7	2.0	0.8	
Miscellaneous	46.2	2.5	9.4	22.5	11.8	
Total	323.9	13.5	120.4	142.7	47.3	
Paper						
Paper & Board Making	93.1	24.4	35.4	22.7	10.6	
Conversion of Paper	23.3	0.9	14.4	4.2	3.8	
Printing & Publishing	19.0	0.2	7.9	7.5	3.4	
Total	135.4	25.5	57.7	34.4	17.8	
Food, etc.						
Dairy (10^6 ℓ milk; MJ/ℓ)	23.2	1.4	16.6	2.3	2.9	
Processed Foods	21.2	0.3	10.8	6.2	3.9	
Bakery	15.7	0.2	5.6	6.4	3.5	
Sugar	26.8	7.7	8.9	8.6	1.3	
Drink	53.3	8.0	15.9	23.3	6.1	
Oils & Fats	13.6	1.6	7.2	3.5	1.3	
Miscellaneous	19.9	2.8	11.6	1.6	3.9	
Tobacco	2.1	-	1.3	0.2	0.6	
Total	175.8	22.0	77.9	52.4	23.5	
Engineering						
Mechanical	73.8	5.2	31.7	22.9	14.0	
Instruments	6.4	-	2.3	2.5	1.6	
Electrical	48.6	1.7	18.0	17.1	11.8	
Vehicles, etc.	113.4	11.4	48.1	35.6	18.3	
Metal Goods	61.8	11.1	25.4	5.9	19.4	
Total	304.0	29.4	125.5	84.0	65.1	
Textiles						
Wool	13.4	3.7	5.5	1.9	2.3	
Cotton	12.1	1.4	4.7	1.6	4.4	
Knitted Goods	8.5	0.5	1.8	4.2	2.0	
Textile Finishing	21.4	2.6	10.5	6.2	2.1	
Jute & Carpets	10.4	2.1	3.6	2.4	2.3	
Miscellaneous Textiles	5.3	0.3	1.6	2.2	1.2	
Synthetic Fibres	33.8	3.4	23.3	2.4	4.7	
Leather Goods	4.3	0.7	2.4	0.7	0.5	
Footwear & Clothing	11.0	1.0	5.8	2.3	1.9	
Total	120.2	15.7	59.2	23.9	21.4	
Grand Total	1,607.4	319.7	579.4	437.2	251.8	19.3

TABLE 5: 1980 Energy Consumption by Final Use (PJ)

Sector/Subsector	Total	Electrochemical & Process Heat > 300°C	Process Heat < 300°C	Space Heating	Motive Power & Lighting
Metal Manufacturing					
Iron & Steel	266.1	231.1	3.0	12.0	20.0
Aluminium	47.0	43.0	0	2.0	2.0
Copper	8.9	7.2	0	0.7	1.0
Lead and Zinc	11.9	8.7	0.6	1.0	1.6
Total	333.9	290.0	3.6	15.7	24.6
Ceramic Materials					
Cement	79.2	64.3	9.0	2.0	3.9
Bricks	19.0	16.1	1.3	0.2	1.4
Refractories	10.3	8.8	0.5	0.4	0.6
Potteries	14.1	9.0	3.2	1.0	0.9
Glass	42.5	37.4	0	3.3	1.8
Misc. Building Materials	49.1	14.1	10.8	17.6	6.6
Total	214.2	149.7	24.8	24.5	15.2
Chemicals					
Inorganic	55.5	23.3	19.4	1.7	11.1
Organic	133.9	24.1	85.7	5.3	18.8
Fertilisers	23.6	2.1	14.4	2.4	4.7
Polymers	19.6	0.8	11.8	3.9	3.1
Dyestuffs	20.1	1.0	10.5	4.0	4.6
Paints	4.7	0	1.6	2.1	1.0
Pharmaceuticals	15.4	0	8.0	3.9	3.5
Detergents	4.9	0	3.8	0.7	0.4
Miscellaneous	46.2	6.9	23.1	6.9	9.3
Total	323.9	58.2	178.3	30.9	56.5
Paper					
Paper & Board Making	93.1	0	61.4	15.4	16.3
Conversion of Paper & Board	23.3	0	7.4	9.7	6.2
Printing & Publishing	19.0	0	1.0	13.7	4.3
Total	135.4	0	69.8	38.8	26.8
Food, etc.					
Dairy (10^6 ℓ milk; MJ/ℓ)	23.2	0	15.9	5.7	1.6
Processed Foods	21.2	0	17.8	1.3	2.1
Bakery	15.7	0	10.1	4.2	1.4
Sugar	26.8	0	22.0	2.8	2.0
Drink	53.3	0	41.3	6.4	5.6
Oils & Fats	13.6	0	11.6	0.8	1.2
Miscellaneous	19.9	0	13.1	3.2	3.6
Tobacco	2.1	0	1.1	0.4	0.6
Total	175.8	0	132.9	24.8	18.1
Engineering					
Mechanical	73.8	6.4	5.1	46.9	15.4
Instruments	6.4	0.5	0.3	4.4	1.2
Electrical	48.6	2.9	2.1	29.9	13.7
Vehicles, etc.	113.4	14.4	8.8	66.9	23.3
Metal Goods	61.8	14.0	12.1	24.0	11.7
Total	304.0	38.2	28.4	172.1	65.3
Textiles					
Wool	13.4	0	6.4	4.6	2.4
Cotton	12.1	0	0.7	6.6	4.8
Knitted Goods	8.5	0	3.3	2.7	2.5
Textile Finishing	21.4	0	18.4	2.2	0.8
Jute & Carpets	10.4	0	2.2	4.6	3.6
Miscellaneous Textiles	5.3	0	2.8	1.3	1.2
Synthetic Fibres	33.8	0	21.6	6.0	6.2
Leather Goods	4.3	0	2.6	1.3	0.4
Footwear & Clothing	11.0	0	1.2	7.9	1.9
Total	120.2	0	59.2	37.2	23.8
Grand Total	1,607.4	536.1	497.0	344.0	230.3

TABLE 6: Comparison of 1980 Energy Consumption Data from 'Digest of UK Energy Statistics' [ref 18] with This Study, by "Digest's" Main Industrial Groups

'Digest' Main Industrial Groups$^+$	'Digest' Energy Consumption (PJ)	This Study Energy Consumption (PJ)
Iron and Steel	302	266
Engineering and Other Metal Trades	394	372*
Food, Drink, Tobacco	198	176
Chemicals and Allied Trades	324**	324
Textiles, Leather and Clothing	99	120
Paper, Printing and Stationery	116	135
Bricks, Tiles, Fireclay and Other Building Material	48	78
China, Earthenware, Glass	67	57
Cement	83	79
Total	1,631	1,607

+ Excluding 'Other Trades' (278 PJ)
* Including non-ferrous metals
** Excludes 113 PJ of feedstock natural gas

TABLE 7: Comparison of 1980 Energy Consumption Data from 'Digest of UK Energy Statistics' [ref 18] with This Study, by Fuel

Fuel Type	'Digest' (PJ)	This Study (PJ)
Solid fuel	336	320
Oil and LPG	543	579
Natural gas	484*	436
Electricity	241	253
Other gases	27	19
Total	1,631	1,607

* Excluding 113 PJ of feedstock supplied to chemical industry

TABLE 8: Total Energy Saving by Conservation Measure in 2000, High Scenario (PJ)

Sector/Subsector	Total (PJ)	Management Measures (PJ)	Additional Equipment Measures (PJ)	Replacement Equipment Measures (PJ)	New Process Technologies (PJ)	Total %
Metal Manufacturing						
Iron & Steel	160.5	75.3	37.9	47.3	0	36.0
Aluminium	13.7	3.5	5.6	2.9	1.7	19.4
Copper	3.4	0.7	1.0	1.0	0.7	29.8
Lead and Zinc	3.7	1.0	1.6	1.1	0	21.3
Total	181.3	80.5	46.1	52.3	2.4	33.2
Ceramic Materials						
Cement	35.1	3.2	13.4	0	18.5	33.1
Bricks	6.3	3.3	1.4	0	1.6	23.1
Refractories	4.0	0.9	2.1	0	1.0	23.4
Potteries	7.7	3.2	0.8	1.6	2.1	48.4
Glass	9.1	3.1	2.7	1.5	1.8	14.8
Misc. Building Materials	11.2	2.2	5.3	3.7	0	15.0
Total	73.4	15.9	25.7	6.8	25.0	24.2
Chemicals						
Inorganic	24.6	3.3	9.0	9.8	2.5	27.1
Organic	72.4	9.6	26.6	29.0	7.2	30.0
Fertilisers	10.5	1.7	4.2	3.9	0.7	27.1
Polymers	10.5	1.4	3.8	4.3	1.0	29.4
Dyestuffs	9.4	1.6	3.8	3.4	0.6	28.8
Paints	2.2	0.3	0.9	0.9	0.1	27.5
Pharmaceuticals	17.8	1.2	4.8	8.9	2.9	36.5
Detergents	3.1	0.4	1.1	1.2	0.4	31.3
Miscellaneous	27.5	3.7	10.1	10.9	2.8	30.1
Total	178.0	23.2	64.3	72.3	18.2	29.8
Paper						
Paper & Board Making	32.9	6.3	7.5	16.6	2.5	26.2
Conversion of Paper	4.8	1.6	1.6	1.6	0	15.0
Printing & Publishing	2.4	1.4	0.5	0.5	0	10.0
Total	40.1	9.3	9.6	18.7	2.5	22.0
Food, etc.						
Dairy (10^6 ℓ milk; MJ/ℓ)	3.9	1.1	1.4	1.4	0	13.6
Processed Foods	5.2	1.2	1.2	2.5	0.3	21.2
Bakery	2.0	0.5	0.5	0.8	0.2	12.7
Sugar	5.3	2.1	1.1	2.1	0	19.5
Drink	19.7	4.0	5.5	8.6	1.6	24.9
Oils & Fats	1.7	0.4	0.3	1.0	0	11.6
Miscellaneous	8.4	1.3	2.6	3.9	0.6	32.2
Tobacco	0.3	0.1	0	0.2	0	11.6
Total	46.5	10.7	12.6	20.5	2.7	20.9
Engineering						
Mechanical	14.8	4.9	6.9	2.0	1.0	15.0
Instruments	1.5	0.5	0.8	0.1	0.1	14.0
Electrical	13.5	4.0	5.5	3.2	0.8	17.0
Vehicles, etc.	23.4	8.4	11.6	1.7	1.7	14.0
Metal Goods	11.6	4.1	5.9	0.8	0.8	14.0
Total	64.8	21.9	30.7	7.8	4.4	14.8
Textiles						
Wool	3.3	0.7	1.0	1.3	0.3	20.0
Cotton	2.7	0.5	0.8	1.1	0.3	20.0
Knitted Goods	2.2	0.5	0.7	0.8	0.2	19.0
Textile Finishing	4.1	1.1	1.6	1.1	0.3	15.0
Jute & Carpets	2.8	0.6	0.8	1.1	0.3	20.0
Miscellaneous Textiles	1.4	0.3	0.4	0.6	0.1	20.0
Synthetic Fibres	7.5	1.5	2.2	3.0	0.8	20.0
Leather Goods	1.9	0.4	0.6	0.7	0.2	30.0
Footwear & Clothing	4.9	1.0	1.4	2.0	0.5	30.0
Total	30.8	6.6	9.5	11.7	3.0	20.5
Grand Total	614.9	168.1	198.5	190.1	58.2	25.2

TABLE 9: Total Energy Saving by Conservation Measure in 2000, Low Scenario (PJ)

Sector/Subsector	Total (PJ)	Management Measures (PJ)	Additional Equipment Measures (PJ)	Replacement Equipment Measures (PJ)	New Process Technologies (PJ)	Total %
Metal Manufacturing						
Iron & Steel	88.8	42.6	21.5	24.7	0	30.1
Aluminium	7.0	2.6	2.5	1.3	0.6	10.8
Copper	2.1	0.5	0.6	0.6	0.4	20.2
Lead and Zinc	2.3	0.8	0.8	0.7	0	15.2
Total	100.2	46.5	25.4	27.3	1.0	26.0
Ceramic Materials						
Cement	32.0	2.9	12.2	0	16.9	33.1
Bricks	3.8	1.9	0.9	0	1.0	15.6
Refractories	2.6	0.6	1.4	0	0.6	23.4
Potteries	6.8	2.8	0.7	1.4	1.9	48.4
Glass	8.0	2.7	2.4	1.3	1.6	14.8
Misc. Building Materials	10.0	2.0	4.7	3.3	0	15.0
Total	63.2	12.9	22.3	6.0	22.0	23.6
Chemicals						
Inorganic	11.6	1.7	6.3	2.7	0.9	18.9
Organic	34.6	5.3	18.6	8.0	2.7	21.1
Fertilisers	4.9	0.9	2.5	1.1	0.4	19.0
Polymers	5.0	0.8	2.5	1.3	0.4	21.0
Dyestuffs	6.2	1.2	3.1	1.7	0.2	23.0
Paints	1.4	0.3	0.7	0.4	0	22.5
Pharmaceuticals	12.2	1.0	4.2	5.6	1.4	33.3
Detergents	1.4	0.2	0.7	0.4	0.1	21.9
Miscellaneous	20.6	3.2	9.5	6.4	1.5	27.2
Total	97.9	14.6	48.1	27.6	7.6	22.9
Paper						
Paper & Board Making	24.7	5.6	5.6	11.3	2.2	22.0
Conversion of Paper	4.5	1.5	1.5	1.5	0	10.0
Printing & Publishing	2.6	1.6	0.5	0.5	0	15.0
Total	31.8	8.7	7.6	13.3	2.2	18.9
Food, etc.						
Dairy (10^6 ℓ milk; MJ/ℓ)	3.1	1.1	1.1	0.9	0	11.0
Processed Foods	5.3	1.1	1.3	2.7	0.2	23.8
Bakery	2.1	0.7	0.7	0.7	0	15.0
Sugar	4.9	1.8	1.8	1.3	0	19.5
Drink	15.2	3.5	4.1	6.2	1.4	22.0
Oils & Fats	1.7	0.6	0.4	0.7	0	12.2
Miscellaneous	6.1	1.2	2.1	2.3	0.5	25.9
Tobacco	0.2	0.1	0	0.1	0	11.6
Total	38.6	10.1	11.5	14.9	2.1	19.3
Engineering						
Mechanical	13.5	4.5	6.3	1.8	0.9	15.0
Instruments	1.5	0.5	0.8	0.1	0.1	14.0
Electrical	13.5	4.0	5.5	3.2	0.8	17.0
Vehicles, etc.	21.0	7.5	10.5	1.5	1.5	14.0
Metal Goods	11.6	4.1	5.9	0.8	0.8	14.0
Total	61.1	20.6	29.0	7.4	4.1	14.8
Textiles						
Wool	2.2	0.4	0.7	0.9	0.2	15.0
Cotton	2.4	0.5	0.7	1.0	0.2	20.0
Knitted Goods	1.8	0.4	0.5	0.7	0.2	17.0
Textile Finishing	3.9	1.0	1.6	1.0	0.3	15.0
Jute & Carpets	2.6	0.5	0.8	1.0	0.3	20.0
Miscellaneous Textiles	1.0	0.2	0.3	0.4	0.1	15.0
Synthetic Fibres	5.0	1.0	1.7	2.0	0.3	15.0
Leather Goods	1.2	0.2	0.4	0.5	0.1	20.0
Footwear & Clothing	4.5	0.9	1.4	1.8	0.4	30.0
Total	24.6	5.1	8.1	9.3	2.1	18.0
Grand Total	417.4	118.5	152.0	105.8	41.1	20.9

TABLE 10: Energy Consumption in 1990, High Output Scenario, by Fuel (PJ)

Sector/Subsector	Total	Coal + Coke	Oil + LPG	Nat. Gas	Elec.	Other Gases
Metal Manufacturing						
Iron & Steel	283.8	191.4	21.5	23.1	24.7	23.1
Aluminium	49.2	3.9	11.3	7.9	26.1	
Copper	8.3	1.3	1.3	3.2	2.5	
Lead and Zinc	12.2	4.0	3.3	2.4	2.5	
Total	353.5	200.6	37.4	36.6	55.8	23.1
Ceramic Materials						
Cement	65.8	55.9	1.3	2.0	6.6	
Bricks	17.9	5.7	5.0	4.1	1.5	1.6
Refractories	12.7	3.3	2.8	5.7	0.9	
Potteries	8.2	0.1	1.4	5.7	1.0	
Glass	43.0	-	12.9	25.8	4.3	
Misc. Building Materials	55.0	11.0	28.1	8.2	7.7	
Total	202.6	76.0	51.5	51.5	22.0	1.6
Chemicals						
Inorganic	58.9	11.5	17.5	18.4	11.5	
Organic	147.5	15.5	48.7	73.3	10.0	
Fertilisers	25.1	1.5	3.9	14.4	5.3	
Polymers	21.6	5.4	5.2	4.9	6.1	
Dyestuffs	21.3	6.0	5.8	7.2	2.3	
Paints	5.0	0.3	1.5	2.2	1.0	
Pharmaceuticals	20.0	4.5	5.1	6.4	4.0	
Detergents	5.4	0.8	1.3	2.3	1.0	
Miscellaneous	52.6	7.5	7.4	24.1	13.6	
Total	357.4	53.0	96.4	153.2	54.8	
Paper						
Paper & Board Making	79.8	27.9	20.7	20.7	10.5	
Conversion of Paper	24.6	2.5	12.8	5.4	3.9	
Printing & Publishing	21.1	2.1	8.0	8.0	3.0	
Total	125.5	32.5	41.5	34.1	17.4	
Food, etc.						
Dairy (10^6 ℓ milk; MJ/ℓ)	26.2	2.6	16.9	2.9	3.8	
Processed Foods	20.7	1.0	9.3	6.2	4.2	
Bakery	14.5	0.3	4.9	5.9	3.4	
Sugar	22.4	7.8	6.3	7.2	1.1	
Drink	54.7	13.7	13.6	20.3	7.1	
Oils & Fats	13.3	2.7	5.9	3.4	1.3	
Miscellaneous	18.8	3.7	9.4	1.7	4.0	
Tobacco	2.0	-	1.0	0.4	0.6	
Total	172.6	31.8	67.3	48.0	25.5	
Engineering						
Mechanical	79.3	7.9	23.8	27.7	19.9	
Instruments	7.7	0.1	2.3	3.1	2.2	
Electrical	56.8	3.4	17.0	20.4	16.0	
Vehicles, etc.	128.1	19.2	42.3	38.4	28.2	
Metal Goods	70.2	14.0	24.7	8.4	23.1	
Total	342.1	44.6	110.1	98.0	89.4	
Textiles						
Wool	13.3	4.8	4.1	2.0	2.4	
Cotton	11.3	1.7	3.7	1.7	4.2	
Knitted Goods	8.7	0.7	1.6	4.2	2.2	
Textile Finishing	22.3	2.9	10.3	7.0	2.1	
Jute & Carpets	10.7	2.3	3.4	2.8	2.2	
Miscellaneous Textiles	5.5	0.6	1.7	2.0	1.2	
Synthetic Fibres	32.1	4.0	19.8	3.5	4.8	
Leather Goods	4.3	0.8	1.6	1.3	0.6	
Footwear & Clothing	11.1	1.1	4.2	3.7	2.1	
Total	119.3	18.9	50.4	28.2	21.8	
Grand Total	1,673.0	457.4	454.6	449.6	286.7	24.7

TABLE 11: Energy Consumption in 1990, Low Output Scenario, by Fuel (PJ)

Sector/Subsector	Total	Coal + Coke	Oil + LPG	Nat. Gas	Elec.	Other Gases
Metal Manufacturing						
Iron & Steel	252.1	150.7	28.8	30.1	23.3	19.2
Aluminium	51.3	2.1	12.3	10.2	26.7	
Copper	8.5	0.8	1.6	3.7	2.4	
Lead and Zinc	12.6	4.0	3.8	2.5	2.3	
Total	324.5	157.6	46.5	46.5	54.7	19.2
Ceramic Materials						
Cement	64.5	55.5	1.3	1.3	6.4	
Bricks	17.4	5.7	4.9	3.8	1.4	1.6
Refractories	10.3	2.7	2.3	4.6	0.7	
Potteries	7.9	0.1	1.3	5.5	1.0	
Glass	40.8	-	12.2	24.4	4.2	
Misc. Building Materials	52.8	10.6	26.9	7.9	7.4	
Total	193.7	74.6	48.9	47.5	21.1	1.6
Chemicals						
Inorganic	52.5	8.5	17.1	16.9	10.0	
Organic	131.8	5.5	51.8	66.8	7.7	
Fertilisers	22.4	0.7	3.2	14.1	4.4	
Polymers	19.3	4.0	5.2	4.1	6.0	
Dyestuffs	19.8	5.1	6.0	6.7	2.0	
Paints	4.7	0.2	1.6	2.1	0.8	
Pharmaceuticals	18.9	3.5	5.4	6.0	4.0	
Detergents	4.8	0.5	1.4	2.1	0.8	
Miscellaneous	48.8	5.5	8.0	22.5	12.8	
Total	323.0	33.5	99.7	141.3	48.5	
Paper						
Paper & Board Making	80.0	24.0	23.2	22.4	10.4	
Conversion of Paper	24.0	2.4	12.5	5.3	3.8	
Printing & Publishing	20.8	2.1	7.9	7.9	2.9	
Total	124.8	28.5	43.6	35.6	17.1	
Food, etc.						
Dairy (10^6 ℓ milk; MJ/ℓ)	24.5	2.4	15.5	2.9	3.7	
Processed Foods	19.2	1.0	8.6	5.7	3.9	
Bakery	13.5	0.3	4.6	5.5	3.1	
Sugar	21.5	7.5	6.0	6.9	1.1	
Drink	51.5	12.9	12.9	19.0	6.7	
Oils & Fats	12.9	2.6	5.8	3.3	1.2	
Miscellaneous	18.7	3.8	9.4	1.7	3.8	
Tobacco	2.0	-	1.1	0.3	0.6	
Total	163.8	30.5	63.9	45.3	24.1	
Engineering						
Mechanical	75.4	7.5	22.4	26.4	19.1	
Instruments	7.7	0.2	2.3	3.1	2.1	
Electrical	56.8	3.4	17.1	20.5	15.8	
Vehicles, etc.	122.1	18.3	40.3	36.7	26.8	
Metal Goods	66.9	13.4	23.4	8.0	22.1	
Total	328.9	42.8	105.5	94.7	85.9	
Textiles						
Wool	13.1	4.7	4.0	2.0	2.4	
Cotton	10.7	1.6	3.4	1.6	4.1	
Knitted Goods	8.4	0.8	1.5	4.0	2.1	
Textile Finishing	21.9	3.0	9.6	7.3	2.0	
Jute & Carpets	10.2	2.3	3.1	2.7	2.1	
Miscellaneous Textiles	5.5	0.5	1.8	2.1	1.1	
Synthetic Fibres	31.1	3.8	19.4	3.3	4.6	
Leather Goods	4.4	0.8	1.8	1.3	0.5	
Footwear & Clothing	10.6	1.1	4.4	3.2	1.9	
Total	115.9	18.6	49.0	27.5	20.8	
Grand Total	1,574.6	386.1	457.1	438.4	272.2	20.8

TABLE 12: Energy Consumption in 2000, High Output Scenario, by Fuel (PJ)

Sector/Subsector	Total	Coal + Coke	Oil + LPG	Nat. Gas	Elec.	Other Gases
Metal Manufacturing						
Iron & Steel	285.4	221.1	7.7	7.8	22.3	26.5
Aluminium	57.0	6.9	11.4	8.5	30.2	
Copper	7.9	1.7	1.0	2.4	2.8	
Lead and Zinc	13.6	4.8	2.7	2.7	3.4	
Total	363.9	234.5	22.8	21.4	58.7	26.5
Ceramic Materials						
Cement	71.4	57.8	1.4	3.6	8.6	
Bricks	21.1	8.7	5.1	3.5	1.6	2.2
Refractories	13.2	3.4	1.3	7.4	1.1	
Potteries	8.2	-	0.7	6.2	1.3	
Glass	52.3	-	10.5	36.6	5.2	
Misc. Building Materials	63.7	25.5	15.9	12.7	9.6	
Total	229.9	95.4	34.9	70.0	27.4	2.2
Chemicals						
Inorganic	66.3	17.1	17.5	19.2	12.5	
Organic	168.9	25.0	48.9	81.0	14.0	
Fertilisers	28.2	2.5	3.5	15.9	6.3	
Polymers	25.1	7.8	4.2	5.6	7.5	
Dyestuffs	23.3	7.2	5.3	7.3	3.5	
Paints	5.7	0.5	1.3	2.6	1.3	
Pharmaceuticals	31.0	8.0	5.5	10.8	6.7	
Detergents	6.8	1.3	1.3	2.9	1.3	
Miscellaneous	63.9	12.0	7.5	28.2	16.2	
Total	419.2	81.4	95.0	173.5	69.3	
Paper						
Paper & Board Making	92.7	46.3	16.7	16.7	13.0	
Conversion of Paper	27.2	5.4	10.9	6.5	4.4	
Printing & Publishing	22.0	2.2	7.7	7.7	4.4	
Total	141.9	53.9	35.3	30.9	21.8	
Food, etc.						
Dairy (10^6 ℓ milk; MJ/ℓ)	24.7	3.7	12.4	3.7	4.9	
Processed Foods	19.5	1.9	7.2	5.8	4.6	
Bakery	13.7	0.4	4.5	5.5	3.3	
Sugar	22.0	9.9	4.4	6.6	1.1	
Drink	59.5	20.8	11.9	18.4	8.4	
Oils & Fats	13.0	4.6	4.5	2.5	1.4	
Miscellaneous	17.7	5.3	6.5	1.7	4.2	
Tobacco	2.0	-	0.8	0.6	0.6	
Total	172.1	46.6	52.2	44.8	28.5	
Engineering						
Mechanical	83.6	16.8	12.6	29.2	25.0	
Instruments	9.1	0.6	2.0	3.7	2.8	
Electrical	65.9	9.9	9.9	24.9	21.2	
Vehicles, etc.	143.8	36.0	21.5	43.2	43.1	
Metal Goods	71.1	24.9	14.2	7.8	24.2	
Total	373.5	88.2	60.2	108.8	116.3	
Textiles						
Wool	13.1	5.9	2.3	2.2	2.7	
Cotton	10.7	2.1	2.7	1.9	4.0	
Knitted Goods	9.3	1.1	1.7	4.2	2.3	
Textile Finishing	23.0	3.4	9.3	8.4	1.9	
Jute & Carpets	11.3	2.8	3.1	3.4	2.0	
Miscellaneous Textiles	5.7	0.8	1.6	2.0	1.3	
Synthetic Fibres	30.1	4.6	16.2	4.6	4.7	
Leather Goods	4.4	0.9	0.9	2.0	0.6	
Footwear & Clothing	11.5	1.1	2.8	5.3	2.3	
Total	119.1	22.7	40.6	34.0	21.8	
Grand Total	1,819.6	622.7	341.0	483.4	343.8	28.7

TABLE 13: Energy Consumption in 2000, Low Output Scenario, by Fuel (PJ)

Sector/Subsector	Total	Coal + Coke	Oil + LPG	Nat. Gas	Elec.	Other Gases
Metal Manufacturing						
Iron & Steel	206.3	143.7	13.8	15.0	16.3	17.5
Aluminium	58.1	4.6	12.8	10.5	30.2	
Copper	8.3	1.2	1.4	3.0	2.7	
Lead and Zinc	12.8	4.2	3.4	2.5	2.7	
Total	285.5	153.7	31.4	31.0	51.9	17.5
Ceramic Materials						
Cement	64.7	52.4	1.3	3.2	7.8	
Bricks	20.5	8.6	4.9	3.4	1.6	2.0
Refractories	8.6	2.2	0.9	4.8	0.7	
Potteries	7.3	-	0.6	5.5	1.2	
Glass	46.3	-	9.3	32.5	4.5	
Misc. Building Materials	56.8	22.7	14.2	11.4	8.5	
Total	204.2	85.9	31.2	60.8	24.3	2.0
Chemicals						
Inorganic	49.7	8.5	15.1	17.1	9.0	
Organic	129.2	6.3	48.3	67.1	7.5	
Fertilisers	21.1	0.7	2.8	13.4	4.2	
Polymers	18.9	3.9	4.8	4.3	5.9	
Dyestuffs	20.8	5.5	6.0	7.1	2.2	
Paints	4.9	0.2	1.7	2.1	0.9	
Pharmaceuticals	24.5	6.3	5.6	6.6	6.0	
Detergents	5.1	0.5	1.4	2.3	0.9	
Miscellaneous	55.1	8.0	8.1	24.1	14.9	
Total	329.3	39.9	93.8	144.1	51.5	
Paper						
Paper & Board Making	87.4	35.0	20.1	20.1	12.2	
Conversion of Paper	25.3	5.1	10.1	6.1	4.0	
Printing & Publishing	23.7	2.4	8.3	8.3	4.7	
Total	136.4	42.5	38.5	34.5	20.9	
Food, etc.						
Dairy (10^6 ℓ milk; MJ/ℓ)	24.7	3.8	12.2	3.7	5.0	
Processed Foods	17.1	1.8	6.3	5.2	3.8	
Bakery	12.1	0.3	3.9	4.9	3.0	
Sugar	20.2	9.1	4.0	6.1	1.0	
Drink	53.9	18.9	10.8	16.7	7.5	
Oils & Fats	12.1	4.3	4.3	2.4	1.1	
Miscellaneous	17.6	5.3	6.5	1.8	4.0	
Tobacco	1.8	-	0.7	0.5	0.6	
Total	159.5	43.5	48.7	41.3	26.0	
Engineering						
Mechanical	76.5	15.3	11.5	26.8	22.9	
Instruments	9.1	0.5	2.0	3.6	3.0	
Electrical	65.9	9.8	9.8	25.0	21.3	
Vehicles, etc.	128.8	32.3	19.3	38.6	38.6	
Metal Goods	71.1	24.9	14.3	7.9	24.0	
Total	351.4	82.8	56.9	101.9	109.8	
Textiles						
Wool	12.6	5.7	2.1	2.1	2.7	
Cotton	9.6	1.9	2.4	1.7	3.6	
Knitted Goods	8.7	1.1	1.6	3.9	2.1	
Textile Finishing	22.0	3.4	8.2	8.8	1.6	
Jute & Carpets	10.2	2.5	2.8	3.1	1.8	
Miscellaneous Textiles	5.6	0.8	1.5	2.0	1.3	
Synthetic Fibres	28.6	4.4	15.3	4.4	4.5	
Leather Goods	4.7	0.8	1.0	2.2	0.7	
Footwear & Clothing	10.4	1.1	2.6	4.6	2.1	
Total	112.4	21.7	37.5	32.8	20.4	
Grand Total	1,578.7	470.0	338.0	446.4	304.8	19.5

TABLE 14: Energy Consumption in 2000, High Output Scenario, by Final Use (PJ)

Sector/Subsector	Total	Electrochemical & Process Heat > 300°C	Process Heat < 300°C	Space Heating	Motive Power & Lighting
Metal Manufacturing					
Iron & Steel	285.4	252.4	3.0	10.0	20.0
Aluminium	57.0	51.9	0	1.5	3.6
Copper	7.9	6.0	0	0.4	1.5
Lead and Zinc	13.6	12.2	0	0.4	1.0
Total	363.9	322.5	3.0	12.3	26.1
Ceramic Materials					
Cement	71.4	52.8	8.0	2.0	8.6
Bricks	21.1	18.3	1.0	0.2	1.6
Refractories	13.2	11.2	0.5	0.5	1.0
Potteries	8.2	5.4	1.5	0.8	0.5
Glass	52.3	44.3	0	4.0	4.0
Misc. Building Materials	63.7	20.1	12.0	22.0	9.6
Total	229.9	152.1	23.0	29.5	25.3
Chemicals					
Inorganic	66.3	30.9	14.8	2.9	17.7
Organic	168.9	24.1	100.8	7.3	36.7
Fertilisers	28.2	2.8	17.9	1.9	5.6
Polymers	25.1	1.4	16.0	1.1	6.6
Dyestuffs	23.3	1.6	12.9	5.5	3.3
Paints	5.7	0	3.5	1.2	1.0
Pharmaceuticals	31.0	0	19.3	8.2	3.5
Detergents	6.8	0	4.9	0.9	1.0
Miscellaneous	63.9	11.5	29.5	9.2	13.7
Total	419.2	72.3	219.6	38.2	89.1
Paper					
Paper & Board Making	92.7	0	62.4	14.0	16.3
Conversion of Paper & Board	27.2	0	12.8	10.0	4.4
Printing & Publishing	22.0	0	0.5	17.1	4.4
Total	141.9	0	75.7	41.1	25.1
Food, etc.					
Dairy (10^6 ℓ milk; MJ/ℓ)	24.7	0	6.3	16.0	2.4
Processed Foods	19.5	0	16.3	1.2	2.0
Bakery	13.7	0	8.4	4.0	1.3
Sugar	22.0	0	18.3	2.4	1.3
Drink	59.5	0	48.7	6.8	4.0
Oils & Fats	13.0	0	10.8	0.8	1.4
Miscellaneous	17.7	0	10.5	3.0	4.2
Tobacco	2.0	0	1.0	0.4	0.6
Total	172.1	0	120.3	34.6	17.2
Engineering					
Mechanical	83.6	6.5	11.5	47.1	18.5
Instruments	9.1	0	1.8	5.0	2.3
Electrical	65.9	2.5	9.0	39.4	15.0
Vehicles, etc.	143.8	12.5	21.0	85.3	25.0
Metal Goods	71.1	15.0	12.0	27.1	17.0
Total	373.5	36.5	55.3	203.9	77.8
Textiles					
Wool	13.1	0	6.4	4.0	2.7
Cotton	10.7	0	0.6	6.1	4.0
Knitted Goods	9.3	0	3.1	3.9	2.3
Textile Finishing	23.0	0	17.9	3.2	1.9
Jute & Carpets	11.3	0	2.5	6.8	2.0
Miscellaneous Textiles	5.7	0	2.5	1.9	1.3
Synthetic Fibres	30.1	0	19.7	5.7	4.7
Leather Goods	4.4	0	2.8	1.0	0.6
Footwear & Clothing	11.5	0	3.1	6.1	2.3
Total	119.1	0	58.6	38.7	21.8
Grand Total	1,819.6	583.4	555.5	398.3	282.4

TABLE 15: Energy Consumption in 2000, Low Output Scenario, by Final Use (PJ)

Sector/Subsector	Total	Electrochemical & Process Heat > 300°C	Process Heat < 300°C	Space Heating	Motive Power & Lighting
Metal Manufacturing					
Iron & Steel	206.3	179.4	2.4	9.5	15.0
Aluminium	58.1	52.9	0	1.5	3.7
Copper	8.3	6.2	0	0.5	1.6
Lead and Zinc	12.8	11.5	0	0.4	0.9
Total	285.5	250.0	2.4	11.9	21.2
Ceramic Materials					
Cement	64.7	47.8	7.3	1.8	7.8
Bricks	20.5	17.7	1.0	0.2	1.6
Refractories	8.6	7.3	0.3	0.3	0.7
Potteries	7.3	4.9	1.3	0.7	0.4
Glass	46.3	39.3	0	3.5	3.5
Misc. Building Materials	56.8	17.9	10.7	19.6	8.6
Total	204.2	134.9	20.6	26.1	22.6
Chemicals					
Inorganic	49.7	23.2	11.1	2.2	13.2
Organic	129.2	18.4	77.1	5.6	28.1
Fertilisers	21.1	2.2	13.4	1.4	4.1
Polymers	18.9	1.0	12.1	0.8	5.0
Dyestuffs	20.8	1.3	11.6	4.9	3.0
Paints	4.9	0	3.0	1.1	0.8
Pharmaceuticals	24.5	0	15.2	6.5	2.8
Detergents	5.1	0	3.7	0.7	0.7
Miscellaneous	55.1	9.9	25.4	7.9	11.9
Total	329.3	56.0	172.6	31.1	69.6
Paper					
Paper & Board Making	87.4	0	58.9	13.2	15.3
Conversion of Paper & Board	25.3	0	11.9	9.3	4.1
Printing & Publishing	23.7	0	0.5	18.5	4.7
Total	136.4	0	71.3	41.0	24.1
Food, etc.					
Dairy (10^6 ℓ milk; MJ/ℓ)	24.7	0	6.3	16.0	2.4
Processed Foods	17.1	0	14.2	1.1	1.8
Bakery	12.1	0	7.4	3.6	1.1
Sugar	20.2	0	16.8	2.2	1.2
Drink	53.9	0	44.1	6.2	3.6
Oils & Fats	12.1	0	10.1	0.7	1.3
Miscellaneous	17.6	0	10.4	3.0	4.2
Tobacco	1.8	0	0.9	0.4	0.5
Total	159.5	0	110.2	33.2	16.1
Engineering					
Mechanical	76.5	5.9	10.5	43.2	16.9
Instruments	9.1	0	1.8	5.0	2.3
Electrical	65.9	2.5	9.0	39.4	15.0
Vehicles, etc.	128.8	11.2	18.8	76.4	22.4
Metal Goods	71.1	15.0	12.0	27.1	17.0
Total	351.4	34.6	52.1	191.1	73.6
Textiles					
Wool	12.6	0	6.2	3.8	2.6
Cotton	9.6	0	0.5	5.5	3.6
Knitted Goods	8.7	0	2.9	3.6	2.2
Textile Finishing	22.0	0	17.1	3.1	1.8
Jute & Carpets	10.2	0	2.3	6.1	1.8
Miscellaneous Textiles	5.6	0	2.4	1.9	1.3
Synthetic Fibres	28.6	0	18.7	5.4	4.5
Leather Goods	4.7	0	3.0	1.1	0.6
Footwear & Clothing	10.4	0	2.8	5.5	2.1
Total	112.4	0	55.9	36.0	20.5
Grand Total	1,578.7	475.5	485.1	370.4	247.7

TABLE 16: Illustrative Future Energy Consumption by Sector
(cf. Figure 15)

	1980	1990 Low	1990 High	2000 Low	2000 High
Metals	334	324	353	286	364
Ceramics	214	194	203	204	230
Chemicals	324	323	357	329	419
Paper	135	125	126	136	142
Food	176	164	173	160	172
Engineering	304	329	342	351	374
Textiles	120	116	119	112	119
Total	1,607	1,575	1,673	1,578	1,820

TABLE 17: Comparison of Illustrative Energy Consumption by Fuel with 1982 Energy Projections (High Output Scenario) (PJ)
(cf. Figure 19)

	1980		1990				2000			
	EP 82	This Study	EP 82 YU	BU	This Study	Unchanged SEC	EP 82 YU	BU	This Study	Unchanged SEC
Coal, etc.	361	339	681	544	481	476	858	673	652	567
Petroleum	543	579	424	558	455	700	375	529	341	866
Natural Gas	435	437	336	405	450	492	237	286	483	620
Electricity	250	252	293	284	287	313	354	354	344	387
Total	1,589	1,607	1,734	1,791	1,673	1,981	1,824	1,842	1,820	2,440

TABLE 18: Comparison of Illustrative Energy Consumption by Fuel with 1982 Energy Projections (Low Output Scenario) (PJ)
(cf. Figure 20)

	1980		1990				2000			
	EP 82	This Study	YL	BL	This Study	Unchanged SEC	YL	BL	This Study	Unchanged SEC
Coal, etc.	361	339	619	492	407	425	733	559	490	437
Petroleum	543	579	398	532	457	648	342	496	338	727
Natural Gas	435	437	326	385	438	453	227	276	446	509
Electricity	250	252	265	265	272	290	300	300	305	325
Total	1,589	1,607	1,608	1,674	1,575	1,816	1,602	1,631	1,579	1,998

TABLE 19: Energy Consumption in 1990, High Output Scenario, Using 1980 SEC (PJ)

Sector	Total	Coal + Coke	Oil + LPG	Nat. Gas	Elec.	Other Gases
Metal Manufacturing	468.7	226.6	74.4	64.1	73.1	30.5
Ceramic Materials	244.3	90.1	82.9	48.2	21.9	1.2
Chemicals	416.7	19.1	123.3	155.7	68.6	
Paper	150.9	28.1	64.5	38.4	19.9	
FDT	196.2	26.7	86.2	56.7	26.6	
Engineering	369.3	35.7	152.5	102.0	79.1	
Textiles	134.7	17.6	66.3	26.8	24.0	
Total	1,980.8	443.9	700.1	491.9	313.2	31.7

TABLE 20: Energy Consumption in 1990, Low Output Scenario, Using 1980 SEC (PJ)

Sector	Total	Coal + Coke	Oil + LPG	Nat. Gas	Elec.	Other Gases
Metal Manufacturing	400.8	189.3	64.5	55.8	65.9	25.3
Ceramic Materials	232.7	88.5	76.3	45.8	21.0	1.1
Chemicals	364.9	17.0	152.0	136.2	59.7	
Paper	145.2	27.3	61.9	36.9	19.1	
FDT	190.1	25.8	83.5	54.9	25.9	
Engineering	354.6	34.3	146.4	98.0	75.9	
Textiles	128.2	16.7	63.1	25.5	22.9	
Total	1,816.5	398.9	647.7	453.1	290.4	26.4

TABLE 21: Energy Consumption in 2000, High Output Scenario, Using 1980 SEC (PJ)

Sector	Total	Coal + Coke	Oil + LPG	Nat. Gas	Elec.	Other Gases
Metal Manufacturing	545.3	260.3	87.1	75.5	87.3	35.1
Ceramic Materials	303.6	115.5	99.5	59.8	27.4	1.4
Chemicals	596.6	27.8	248.5	222.6	97.7	
Paper	182.5	34.4	77.8	46.4	23.9	
FDT	222.2	30.2	97.7	64.1	30.2	
Engineering	438.0	42.4	180.8	121.0	93.8	
Textiles	151.4	20.0	74.6	30.1	26.7	
Total	2,439.6	530.6	866.0	619.5	387.0	36.5

TABLE 22: Energy Consumption in 2000, Low Output Scenario, Using 1980 SEC (PJ)

Sector	Total	Coal + Coke	Oil + LPG	Nat. Gas	Elec.	Other Gases
Metal Manufacturing	385.6	174.5	63.5	55.2	69.3	23.1
Ceramic Materials	267.5	101.8	87.7	52.7	24.1	1.2
Chemicals	427.5	20.0	178.0	159.5	70.0	
Paper	168.7	31.8	71.9	42.9	22.1	
FDT	200.5	27.2	88.1	57.9	27.3	
Engineering	412.2	39.9	170.2	113.9	88.2	
Textiles	136.8	17.9	67.4	27.2	24.3	
Total	1,998.8	413.1	726.8	509.3	325.3	24.3

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